

Bryozoan Fauna in the Jizodo Formation (Pleistocene), Boso Peninsula, Honshu, Japan

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Abstract Five bryozoan associations are classified by the R-mode approach using a number of fragments of colonies, and their facies-related distribution is studied in the Jizodo Formation. Twenty-three bryozoan species, including three new to science, are described.

The *Cellaria punctata*-*Thalamoporella novaehollandiae* Association, including "sand fauna" species, and the *Myriozoum serratum*-*Microporella californica* Association, including many erect rigid species, are abundant in shelf sand facies. The *Verminaria areolae*-*Hippoporina purpurata* Association, characterized by the active colonization of encrusting species on molluscan shells, is abundant in non-deltaic nearshore facies. The *Celleporella hyalina*-*Watersipora aterritima* Association, including many species living in the circumlittoral zone of the Kanto region, is common in all facies except for the offshore facies called "the Jizodo Fossil Zone". The *Aimulosia aculeata* Association is characteristic in the *Tapes* beds interpreted as bay mouth sand facies.

Key words: Bryozoan fauna, Jizodo Formation, Pleistocene, Boso Peninsula, Japan.

Pleistocene marine deposits are widely distributed in the middle to northern part of the Boso Peninsula. The Simosa Group occupies the upper layers and is mainly composed of shallow-marine sands; it shows characteristic cyclothem reflecting glacio-eustatic sea-level changes. The Jizodo Formation is the lowest part of the Shimosa Group and contains many fossils of marine animals. For example, Ogose (1959, 1961a, b, 1968), Aoki *et al.* (1971), Aoki and Baba (1980), Ohara (1973) and Kondo (1989) did studies on the molluscan fauna.

Sakakura (1935b) described 77 bryozoan species including some cyclostomatous ones from the shell bed he called "the Jizodo Fossil Zone". This was the first study on Japanese Cenozoic bryozoans. He published a preliminary report on the bryozoans from some other localities of the Boso Peninsula (Sakakura, 1936), but only those from Tako-machi have been described since then (Sakakura, 1938).

I have collected many bryozoan remains from sixteen localities of the Jizodo Formation including horizons other than "the Jizodo Fossil Zone" (Arakawa, 1982MS). In this paper, the cheilostomatous bryozoans from the Jizodo Formation are classified into an "association" on the basis of their facies-related distribution.

The results of bryozoological studies in recent years are applied to the comparison of their characters.

Twenty-three species of Cheilostomata, including three new to science in the genera *Hippoporina*, *Calloporina* and *Lepraliella*, are described. The diagnosis of the genus *Cyclocolposa* is emended. Two genera, *Aimulosia* and *Phylactella* have been found for the first time in Japan.

Depository. All the specimens referred to in the palaeontological descriptions in the present articles are stored in the Collections of the Natural History Museum and Institute, Chiba (CBM).

Stratigraphy

The Jizodo Formation is the lowest part of the Shimosa Group (Fig. 1). The Shimosa Group is characterized by sedimentary cycles which start from fresh- to brackish-water muds and end with shallow marine sands (Tokuhashi and Endo, 1984). Many students have concluded that these cycles resulted from the Quaternary glacio-eustatic sea-level changes (*e.g.*, Kanto Quaternary Research Group, 1980). In the Jizodo Formation, the shell bed called "the Jizodo Fossil Zone" by Sakakura (1935a) corre-

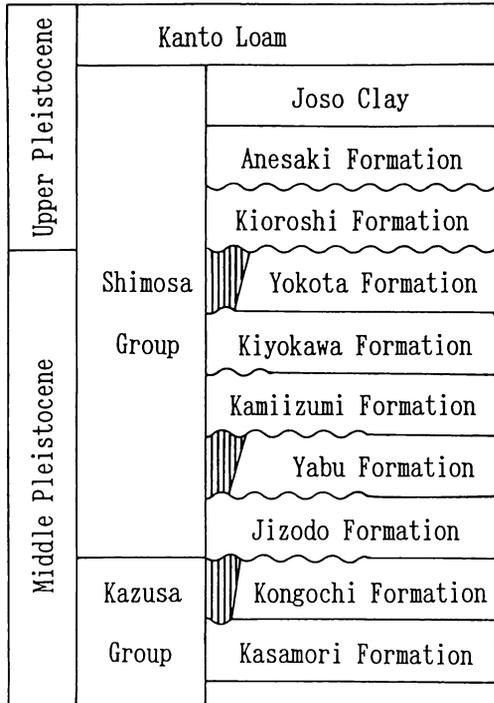


Fig. 1. Stratigraphy of the Middle to Upper Pleistocene deposits of Boso Peninsula, based on Tokuhashi and Endo (1984) and Sato (1993).

sponds to the horizon of maximum phase of transgression. This horizon can be traced with several key beds.

The marker tephra in the Jizodo Formation have been described by Aoki *et al.* (1962), Mitsunashi (1973), Sugihara *et al.* (1978) and Tokuhashi and Endo (1984). The coarse-grained white pumice bed called Kn-1 and the pinkish ash bed called TE-5 are conspicuous in "the Jizodo Fossil Zone" (Sugihara *et al.*, 1978). Suzuki and Sugihara (1983) dated the ash bed TE-5 to about 0.39 Ma by the fission track method. Above them, there are coarse-grained scoria beds, coarse-grained pumice beds and fine-grained scoria beds named J5 to J11 by Tokuhashi and Endo (1984). They are widely distributed around the Koito River and northeastern localities. The white ash bed called Iy, which is situated in the lower part of the formation, is also important. Around the type locality (Loc. 11) and Kongochi (Loc. 17) this tephra is found in the thick mud beds called the Izumiyatsu Muds. The uppermost part of

the Izumiyatsu Muds contains the layers of peat, and the penetration by burrows starts on the top of these mud beds. These facts show that the transgression started soon after the deposition of Iy.

The underlying formation is the Kongochi Formation in the northeastern localities. The uppermost part of the Kongochi Formation contains *Macaronichnus* burrows which are found in the foreshore deposits of sandy beaches (Kikuchi, 1972; Nara and Kotake, 1992). This fact shows that the sedimentary basin of the Jizodo Formation started as a coastal plain in the northeast of the region. On the other hand, the contact between the Jizodo Formation and the underlying formations (the Kongochi and Kasamori Formations) is unconformable around the Koito River. According to Machida *et al.* (1980), the basal erosion reaches to the horizon just above the tephra named Ks-11.5B in the Kasamori Formation below the Kongochi Formation. Around the Kori-dam (Loc. 27), the muddy beds fill an incised valley. Between Hogisaku (Loc. 2) and Nishiyatsu (Loc. 5), the basal boundary of the formation corresponds to the "ravinement surface" (see Ito and Ohara, 1991). This type of boundary lies about 1 m below the horizon of coarse-grained scoria beds between Hogisaku and Yatsu (Loc. 3) and about 20 m below the same horizon between Oi (Loc. 4) and Nishiyatsu.

The overlying formation is the Yabu Formation. The Jizodo Formation is conformably overlain by the Yabu Formation at most localities between Okido (Loc. 18) and Terayatsu (Loc. 19), but basal gravels of the Yabu Formation are widely distributed around the type locality (Loc. 21). Around the Koito River, the incised valley fill deposits in the Yabu Formation are distributed around Owada (Loc. 1), and the "ravinement surface" is observed at Neriki (Loc. 23).

Sedimentary Facies

Bryozoan remains in the Jizodo Formation were collected from six types of sedimentary facies: Facies I, II, III, IV, V and VI.

Facies I: The shell bed at Locs. 3, 5, 8, 9, 11, 13 and 14, which is named "the Jizodo Fossil

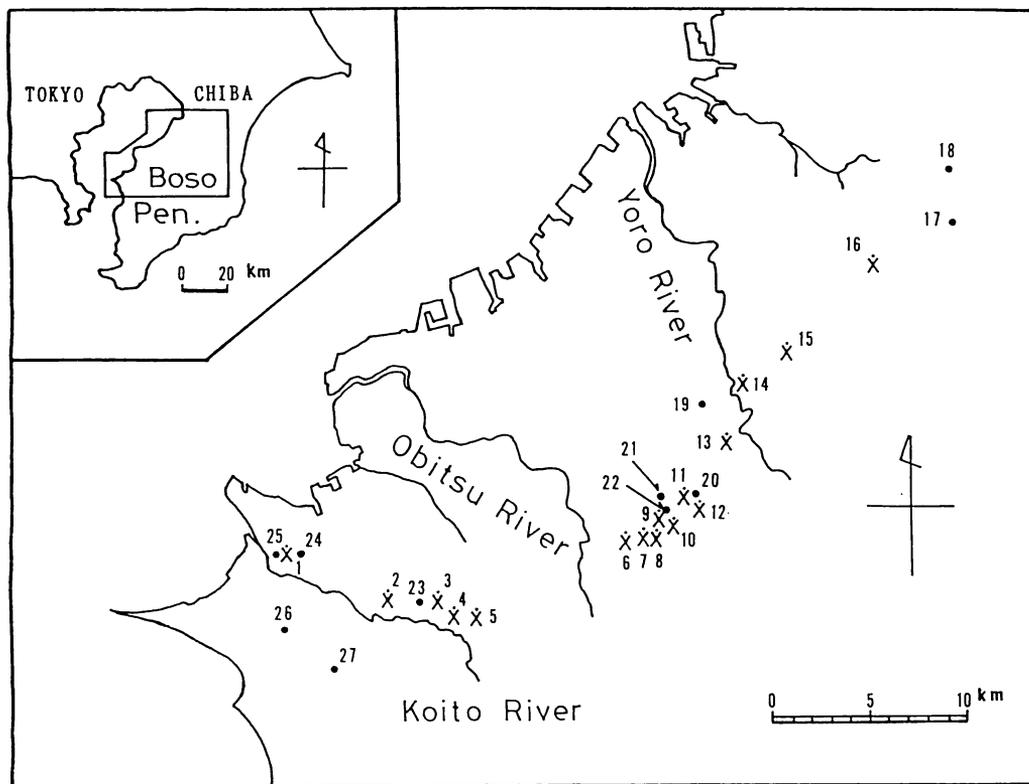


Fig. 2. Map of collecting localities (1-16) and additional ones (17-27). 1. Owada, 2. Hogisaku, 3. Yatsu, 4. Oi, 5. Nishiyatsu, 6. Ichinosawa, 7. west of Nanamagari, 8. the Nanamagari Shrine, 9. Atebi, 10. Izumiyatsu, 11. Jizodo, 12. Ichinono, 13. Yamadakubo, 14. Myoko, 15. Kawazai, 16. the Nagara-dam, 17. Kongochi, 18. Okido, 19. Terayatsu, 20. Tanbara, 21. Yabu, 22. Mariyatsu, 23. Neriki, 24. Honnawa, 25. Hitomi, 26. Hongo, 27. the Kori-dam.

Zone" by Sakakura (1935a), consists of graded or parallel laminated sands in the lower part and highly bioturbated muddy sands in the upper part. Molluscan shells of the *Aequipecten-Glycymeris* Assemblage (Aoki and Baba, 1980) are concentrated as lag deposits in poorly-sorted sand beds showing normal grading. They are also found in the lenticular shell beds in the bioturbated muddy sands. Low-angle parallel lamination is observed in the lower part of this sedimentary facies.

According to Kondo (1989), the molluscan association in this shell bed is now found at about 80-100 m depth, influenced by the warm Kuroshio. Additionally, the rareness of laminated sands suggests that the deposition of this facies is not attributed to oscillatory currents of the nearshore zone. Therefore, this facies can be interpreted as turbidity current deposits formed in the offshore zone of middle to inner

shelf.

Facies II: Cross-stratified shell beds at Locs. 4, 5, 6, 8 and 16 are characterized by well-preserved fossils of marine benthos concentrated along the foreset laminae. Ohara (1973) explained that the molluscan fauna at the Kori-dam is mixed with Kuroshio and Oyashio elements, and that it is composed of euneritic-mesoneritic and subneritic-bathyneric dwellers. The shell bed at Nishiyatsu is also composed of such mixed molluscan fauna called the *Maetra-Glycymeris* Assemblage by Aoki and Baba (1980). Cross-stratification and mixed molluscan fauna show that the deposition occurred under strong currents. However, the abundance of post-mortem epizoans on molluscan shells, including bryozoans, suggests that there was a rather long inactive period of sedimentation. The low rate of sedimentation which caused the increase of sessile

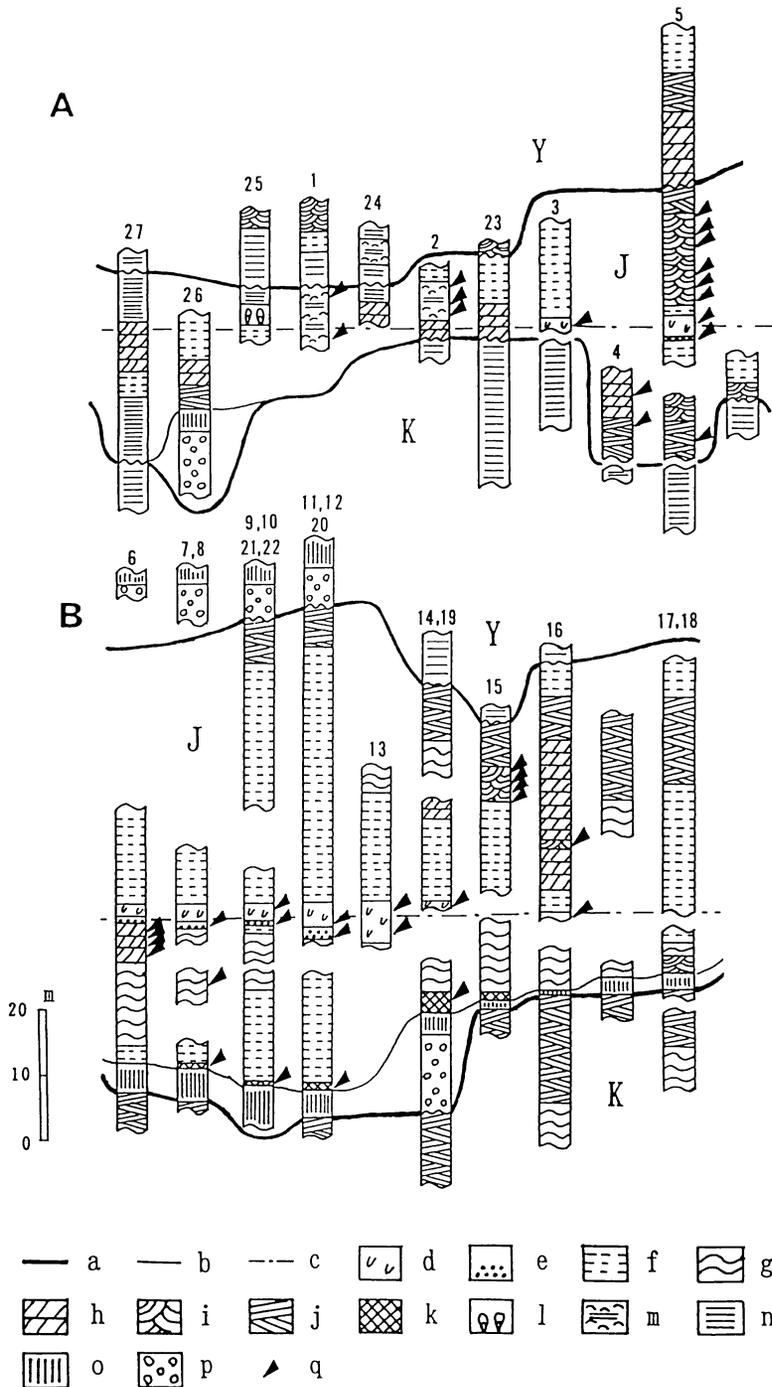


Fig. 3. Columnar sections showing sedimentary facies and collecting horizons. A. Around the Koito River, B. The northeastern localities. a: boundary of formations, b: ravinement surface, c: horizon of maximum transgression, d: bioturbated muddy sands in "the Jizodo Fossil Zone", e: normal grading in "the Jizodo Fossil Zone", f: weakly laminated sands, g: hummocky and swaley cross-stratification, h: tabular cross-stratification, i: trough cross-stratification, j: low-angle cross-stratification, k: bioturbated muddy sands in "the Izumiyatsu Fossil Zone", l: oyster beds, m: sand-dominated alternation of sands and muds, n: mud-dominated alternation of sands and muds, o: fresh- or brackish-water muds (the Izumiyatsu Muds), p: basal gravels, q: collecting horizons of bryozoan remains. Y: Yabu Formation, J: Jizodo Formation, K: Kongochi and Kasamori Formations. Localities shown in Figure 2.

animals may indicate a non-deltaic shallow-marine environment.

The herringbone-cross structure partly observed in this facies indicates reversing currents such as tidal currents. If the genesis of this facies was tidal currents, its long period, reflected in the abundance of epizoans on molluscan shells, may be interpreted as a neap-spring cycle.

Facies III: Molluscan shells of the *Spisula-Mactra* Assemblage (Aoki and Baba, 1980) and fossils of other marine benthos are concentrated as lag deposits in the trough cross-laminae at Locs. 2, 4 and 5. These shell beds are regarded as transgressive lags on the ravinement surface. At these localities, the lowest part of the formation consists of graded or weakly laminated gravels and trough cross-stratified sands interpreted as upper shoreface deposits. Bryozoans often attach themselves to gravelly materials, which may have been transported by strong waves and currents during storms. Abundant epizoans on molluscan shells and stones also suggest a long interval of sedimentation as inferred in Facies II.

Facies IV: Molluscan shells of the *Spisula-Mactra* Assemblage (Aoki and Baba, 1980) are also concentrated as lag deposits in the trough cross-laminae at Loc. 15. Post-mortem epizoans are rare, however, on molluscan shells in this shell bed, suggesting that the sedimentation was more rapid than in Facies II and III. So this sedimentary facies may be interpreted as upper shoreface deposits in the circum-deltaic nearshore zone. Hummocky and swaley cross-stratification indicating storm-generated oscillation and currents is also observed in the same horizon (Dott and Bourgeois, 1982; Yagishita *et al.*, 1992).

Facies IV is a part of the depositional sequence characterized by the predominance of endofauna. In the fine-grained sand beds overlaid with this facies, there are scattered molluscan shells of the *Patinopecten-Turritella* Assemblage (Aoki and Baba, 1980) and burrows such as *Rosselia*. Kondo (1987) interpreted one group of the large burrows observed in these fine-grained sand beds as those of immobile bivalves like *Panopea japonica*. On the other hand, trace fossils, such as *Ophiomorpha*, *Planolites*,

Palaeophycus, *Skolithos* and *Macaronichnus*, are abundant in cross-stratified or parallel laminated sand beds above this facies. The predominance of endofauna may also indicate an active supply of fine-grained materials.

Facies V: The shell bed of the *Tapes* Assemblage (Aoki and Baba, 1980) at Loc. 1 shows sand-dominated alternating beds of sands and muds. Sand beds show the "inclined cross-stratification". The concentration of abraded shells along cross-laminae suggests long-term drifting. On the other hand, this facies changes laterally to the mud-dominated alternating beds of sands and muds containing many ostracods, burrows and autochthonous oyster shells (Yajima, 1978). This facies is, therefore, interpreted as deposits transported from tidal inlets into the bay-bottom. Its greater dip may show the lateral accretion of flood-tidal delta.

Facies VI: The shell bed at Locs. 7, 10, 12 and 14, named "the Izumiyatsu Fossil Zone" by Sakakura (1935a), is the transgressive lag formed above the coastal plain constructed by the Kongochi Formation. Kondo (1989) reported drastic upward changes of molluscan fauna in this shell bed. According to his report, the molluscan association changes from the Intertidal or Inner-Bay Mud Association to the Sand-Gravel Association, and the preservation of shells in their life position suggests that their concentration can never be attributed to any post-mortem process. So this sedimentary facies may be interpreted as bay-bottom deposits. However, the presence of allochthonous fossils of sessile invertebrates, such as bryozoans and barnacles, suggests the influence of a flood tidal current.

Bryozoan Fauna

More than 80 species in 59 genera of cheilostomatous bryozoans were found in 40 samples at 16 localities of the Jizodo Formation. The bryozoan specimens were picked up from the sieved sediments bigger than 0.5 mm in diameter.

A complete quantitative analysis cannot be made for fossil bryozoans because they are usually fragmentary. In particular, the rank of each species in the sample cannot be determined at all. However, if the difference in size

Table 1. Distribution of Bryozoa (Cheilostomata) from the Jizodo Formation. A: abundant ($50\% \leq a_i$), C: common ($20\% \leq a_i < 50\%$), ++: rate ($5\% \leq a_i < 20\%$), +: very rate ($0\% < a_i < 5\%$).

Zoarial forms and taxa	Facies					
	I	II	III	IV	V	VI
〈Bilaminar erect rigid〉						
<i>Membranipora savartii</i> (Audouin)		A	+	C		
<i>Steginoporella magnilabris</i> (Busk)		A				
<i>Thalamoporella lioticha</i> (Ortmann)		A				
<i>Escharoides adeonelloides</i> (Ortmann)	A	C				
<i>Adeonellopsis yarraensis</i> (Waters)	A	+				
〈Cylindrical erect rigid〉						
<i>Thalamoporella novaehollandiae</i> (Haswell)	A	++	++	+		
<i>Haswellina</i> (?) sp.	A	++				
<i>Celleporina geminata</i> (Ortmann)	++	A		+		
<i>Myrizooum serratum</i> Mawatari	+	C	+	++		
<i>M. subgracile</i> d'Orbigny	+	A	+	+		
〈Fenestrate erect rigid〉						
<i>Sertella</i> spp.	+	A	+	+		
〈Rooted and jointed erect〉						
<i>Microporina articulata</i> (Fabricius)	+	A				
<i>Cellaria</i> spp.	C	C	+	++		
<i>Caberea lata</i> Busk	++	A	+	C		
〈Rooted conical or flabellate〉						
<i>Conescharellina</i> spp.	C	A	+	++		
<i>Flabellopora</i> spp.	C	C	+	++		
〈Free-living〉						
<i>Cupuladria elongata</i> Sakakura	C	A				
〈Multilaminar encrusting〉						
<i>Antopora tincta</i> (Hastings)			A			
<i>Verminaria areolae</i> Sakakura		C	A			
<i>Celleporella hyalina</i> (Linnaeus)		++	+	A	+	++
<i>Hippoporina purpurata</i> sp. nov.		A	C			
<i>Cyclocolpoda costulata</i> (Canu and Bassler)	++	++	A	++	++	
<i>Rhynchozoon rostratum</i> (Busk)		C	A			
<i>Rhynchozoon</i> sp.	+	A	C			+
<i>Celleporina porosissima</i> Harmer		A		C		C
<i>C. radiata</i> (Ortmann)	++	A	+	C		
<i>Celleporaria subdescostilsii</i> (Sakakura)	+	A	C	++		++
<i>C. tridenticulata</i> (Busk)		A				
<i>Osthimosia multiavicularia</i> Sakakura	C	C	C			

and the state of preservation of the bryozoan fragments are adequately considered, an approximate so-called R-mode analysis can be made. Therefore, in this study, the average number of fragments in each taxon is compared facies by facies. The abundance of each bryozoan taxon in each facies is expressed as

$$a_i = 100(A_i / \sum A_i)$$

where A_i is the average number of fragments of each taxon per 100 g of sediments in Facies

i (Table 1).

Most of the bryozoan species in the Jizodo Formation are distributed over three to four types of sedimentary facies. The segregation of bryozoans is generally not sharp, reflecting the fact that they often compete on the same substratum. Even if this fact is taken into consideration, however, the difference in their peak of abundance may suggest some parts of their segregation. In the case of the Jizodo Formation, five bryozoan associations are dis-

Bryozoan fauna in the Jizodo Formation

Table 1. (continued)

Zoarial forms and taxa	Facies					
	I	II	III	IV	V	VI
⟨Unilaminar encrusting⟩						
<i>Callopora kadusensis</i> (Sakakura)		A				
<i>Tegella unicornis</i> (Fleming)	C	C	C	++		
<i>Chaperia acanthina</i> (Lamouroux)		A		C		
<i>Onychocella subsymmetrica</i> (Canu and Bassler)	++	A			+	
<i>Rosseliana sibatai</i> Sakakura	++	A	C			
<i>Micropora coriacea</i> (Johnston)	++	C	A	+		
<i>Labioporella elegans</i> Sakakura	C	C	++	++		
<i>Monoporella fimbriata</i> Canu and Bassler	A					
<i>Cribrilaria radiata</i> (Moll)		A				
<i>Reginella furcata</i> (Hincks)		C	++	A	+	
<i>Hippothoa flagellum</i> Manzoni	++	A				
<i>Eurystomella bilabiata</i> (Hincks)	+	A	++			
<i>Exochella longirostris</i> Jullien		A		C		
<i>Escharoides jacksoni</i> (Waters)		C	++	A		++
<i>Watersipora aterrima</i> (Ortmann)		+		A		
<i>Cryptosula reticulata</i> (Okada)		++		A		
<i>Mucropetraliella philippinensis</i> (Canu and Bassler)		C		A		
<i>Schizoporella</i> sp.				A		
<i>Arthropoma cecilii</i> (Audouin)		A				
<i>Buffonellodes granulosa</i> (Sakakura)	A					
<i>Codonellina montferrandii</i> (Audouin)		+		A		+
<i>Schizomavella auriculata</i> (Hassall)	+	C	C	+	+	
<i>S. ternata</i> (Ortmann)		A				
<i>Escharella major</i> (Hincks)	A					
<i>Smittina nodai</i> Hayami		A				
<i>Porella porifera</i> (Hincks)		A	C	++		
<i>Smittoidea pacifica</i> Soule and Soule	++	C	C	C		
<i>S. prolifica</i> Osburn		+		A	++	
<i>Parasmittina tropica</i> (Waters)		C	++		C	
<i>P. unispinosa</i> (Waters)		A		C		
<i>Parasmittina</i> sp. cf. <i>P. parsevaliformis</i> Soule and Soule	++	C	C	++		
<i>Parasmittina</i> sp. A	++	++	C	C	++	
<i>Parasmittina</i> sp. B		C			A	
<i>Pleurocodonellina signata</i> (Waters)	++	A	++			
<i>Microporella californica</i> (Busk)	+	A	++	++	++	+
<i>M. ciliata</i> (Pallas)		A		C		
<i>Microporella</i> sp. cf. <i>M. gibbosula</i> Canu and Bassler	A					
<i>Calloporina hayamiae</i> sp. nov.		A				
<i>Fenestulina malusii</i> (Audouin)		++		A		
<i>Lepraliella biporosa</i> sp. nov.		A		++	C	
<i>Aimulosia aculeata</i> Canu and Bassler					A	
<i>Cleidochasma fallax</i> (Canu and Bassler)	A	++	++	C		
<i>Stephanosella biaperta</i> (Michelin)	+	A	C			
<i>Phylactella</i> sp.		C			A	
<i>Schismopora tokunagai</i> Sakakura	A					
Average number of fragments per 100 g of sediments	76	273	35	85	3	4

tinguished on the basis of their peak of abundance. To name each association, one or two living and ecologically characteristic species are selected. All of them are also found in other formations of the Shimosa Group.

1. The *Cellaria punctata*-*Thalamoporella novaehollandiae* Association

Bilaminar erect rigid colonies: *Escharoides adeonelloides*, *Adeonellopsis yarraensis*

Cylindrical erect rigid colonies: *Thalamopo-*

rella novaehollandiae, *Haswellina* (?) sp.

Rooted and jointed erect colonies: *Cellaria* spp. (mainly *C. punctata*)

Rooted and conical or flabellate colonies: *Conescharellina* spp., *Flabellopora* spp.

Free-living colonies: *Cupuladria elongata*

Unilaminar encrusting colonies: *Labioporella elegans*, *Monoporella fimbriata*, *Buffonellodes granulosa*, *Escharella major*, *Microporella* cf. *gibbosula*, *Cleidochasma fallax*, *Schismopora tokunagai*

These species are mainly found in Facies I and II.

They compose the main part of the warm water fauna formed during the maximum phase of transgression. Most of the species in this association are distributed in the tropical and subtropical region, except for *Escharoides adeonelloides* and *Labioporella elegans*, which live only around Japan, and *Buffonellodes granulosa* and *Schismopora tokunagai*, which are found only in Japanese Pleistocene deposits.

The "sand fauna" bryozoans sensu Cook (1966) are characteristic of this association. The internodes of *Cellaria punctata* are among most abundant fragments in the Jizodo Formation. Rooted colonies of *Cellaria*, *Conescharellina* and *Flabellopora* are known to be bryozoans which can attach to sand grains with root-like heterozooids. The free-living colonies of *Cupuladria encrusta* a single sand grain with a multizoooidal ancestrular complex (Cook and Chimonides, 1981). This specific group is more abundant in Facies II than Facies I. Colonization of "sand fauna" bryozoans in the Jizodo Formation seems to have been more active on the coarser particles.

The fragments of *Thalamoporella novaehollandiae* are well preserved in Facies I but they are often broken up into zooids in other facies. This fact suggests that the vinculariiform colonies of this species were formed mainly in an offshore environment. The same inference can be made concerning the adeoniform colonies of *Adeonellopsis yarraensis*.

2. The *Myriozoum serratum*-*Microporella californica* Association

Bilaminar erect rigid colonies: *Steginoporella*

magnilabris, *Thalamoporella lioticha*

Cylindrical erect rigid colonies: *Celleporina geminata*, *Myriozoum serratum*, *M. subgracile*

Fenestrate erect rigid colonies: *Sertella* spp.

Rooted and jointed erect colonies: *Microporina articulata*

Multilaminar encrusting colonies: *Celleporaria tridenticulata*

Unilaminar encrusting colonies: *Callopora kadusensis*, *Onychocella subsymmetrica*, *Cribrilaria radiata*, *Hippothoa flagellum*, *Eurystomella bilabiata*, *Schizomavella ternata*, *Arthropoma cecilii*, *Smittina nodai*, *Pleurocodonellina signata*, *Microporella californica*, *Calloporina hayamiae*

These species are abundant only in Facies II.

This association includes the largest number of erect rigid species among the five bryozoan associations studied. Schopf (1969) stated that wave energy causes direct mechanical damage and turbulence to limit the growth of erect rigid species, especially branching ones (see also Winston, 1979).

Among these erect rigid species, the fragments of *Myriozoum serratum* and *Celleporina geminata* readily remain as sedimentary particles because they have relatively hard frontal walls. They appear to rank highly in many samples. *Sertella* spp. also provide a large number of fragments, but their preservation is very poor.

Microporella californica is the only species found from all sedimentary facies in the Jizodo Formation. This species often forms large colonies and can attach to the convex side of molluscan shells or to rounded gravels.

Seven species, *Steginoporella magnilabris*, *Celleporina geminata*, *Onychocella subsymmetrica*, *Cribrilaria radiata*, *Arthropoma cecilii*, *Pleurocodonellina signata* and *Celleporaria tridenticulata*, are tropical to subtropical. On the contrary, *Myriozoum subgracile*, *Microporina articulata* and *Eurystomella bilabiata* are boreal to subboreal. *Hippothoa flagellum* is cosmopolitan. *Microporella californica* seems to be widely distributed in the Pacific Ocean, mainly in the temperate zone. *Thalamoporella lioticha*, *Myriozoum serratum* and *Schizomavella ternata* seem to be local Japanese species.

3. The *Verminaria areolae*–*Hippoporina purpurata* Association

Multilaminar encrusting colonies: *Antropora tincta*, *Verminaria areolae*, *Hippoporina purpurata*, *Cyclocolpota costulata*, *Rhynchozoon rostratum*, *Rhynchozoon* sp., *Celleporaria subdescostilsii*

Unilaminar encrusting colonies: *Rosseliana sibatai*, *Micropora coriacea*, *Schizomavella auriculata*, *Stephanosella biaperta*, *Porella porifera*, *Parasmittina* cf. *parsevaliformis*

These species are mainly found in Facies II and III.

This association is characterized by multilaminar encrusting colonies of *Antropora*, *Verminaria*, *Hippoporina*, *Cyclocolpota*, *Rhynchozoon* and *Celleporaria*. *Antropora*, *Verminaria*, *Hippoporina* and *Cyclocolpota* form plate-like multi-layers of zooids. Nishizawa (1985) found regularly spaced mounds and thin "frontal walls" in the ectoproctolith of *Antropora tincta* collected at Oi (Loc. 4). *Cyclocolpota costulata* shows the secondary calcification filling the orifice, which is similar to the "frontal walls" of *Antropora tincta*. Multilaminar colonies of *Verminaria areolae* and *Hippoporina purpurata* are constructed by spiral growth. *Rhynchozoon* and *Celleporaria* show nodular colonies of zooids which are erect distally.

Active colonization of unilaminar encrusting bryozoans including *Antropora*, *Verminaria*, *Hippoporina* and *Cyclocolpota* is also conspicuous. They cover molluscan shells extensively in many cases and often attach to both sides of shells.

The mixture of zoogeographical groups is distinct in this association. The temperate zone and local Japanese species make up the largest number in the five associations. *Antropora tincta*, *Cyclocolpota costulata* and *Rhynchozoon rostratum* are distributed in the tropical and subtropical region. *Stephanosella biaperta* is boreal, and *Micropora coriacea* is cosmopolitan. *Schizomavella auriculata* and *Porella porifera* are regarded as species of the temperate zone. *Rosseliana sibatai*, *Verminaria areolae* and *Hippoporina purpurata* seem to be local Japanese species.

4. The *Celleporella hyalina*–*Watersipora aterrima* Association

Bilaminar erect rigid colonies: *Membranipora savartii*

Rooted and jointed erect colonies: *Caberea lata*

Multilaminar encrusting colonies: *Celleporella hyalina*, *Celleporina porosissima*, *C. radiata*

Unilaminar encrusting colonies: *Chaperia acanthina*, *Reginella furcata*, *Exochella longirostris*, *Escharoides jacksoni*, *Watersipora aterrima*, *Cryptosula reticulata*, *Mucropetraliella philippinensis*, *Schizoporella* sp., *Codonellina montferrandii*, *Microporella ciliata*, *Fenestulina malusii*, *Smittoidea prolifica*, *Parasmittina unispinosa*, *Parasmittina* sp. A

These species are mainly found from Facies II and IV.

Most of the species in this association live in the circumlittoral zone in Japan. Among them, *Membranipora savartii*, *Caberea lata*, *Celleporella hyalina*, *Watersipora aterrima* (as *W. cucullata watersi*), *Exochella longirostris*, *Microporella ciliata*, *Fenestulina malusii* and *Celleporina radiata* were reported from the coast of the Kii Peninsula by Mawatari (1952b). *Membranipora savartii*, *Watersipora aterrima* (as *W. subovoidea*), *Codonellina montferrandii*, *Smittoidea prolifica* and *Fenestulina malusii* were reported as fouling bryozoans in Japanese harbors (Mawatari, 1967; Long and Rucker, 1969). Nishizawa (1985MS) observed five bryozoan species, *Bugula neritina*, *Tricellaria occidentalis*, *Watersipora aterrima* (as *W. subovoidea*), *Fenestulina malusii* and *Celleporina porosissima* encrusting the seagrass *Zostrea* at the mouth of Aburatsubo Bay in the Miura Peninsula. Additionally, I collected thirty-seven bryozoan species which are encrusting oyster shells and seaweeds from the Pacific coast of the Kanto region (Table 2). Twelve of these species are included in this association.

Nodular colonies of *Celleporina radiata* are among the most abundant fragments in the Jizodo Formation. In many cases, however, the zooids are entirely filled with sand grains and cements. The spherical shape of colonies in this species may have facilitated their relatively extensive post-mortem transportation.

The zoogeographical mixture is also distinct

Table 2. Recent Bryozoa (Cheilostomata) encrusting oyster shells and seaweeds from the Pacific coast of the Kanto region (after Arakawa, 1992). Asterisk shows the species in the *Celleporella-Watersipora* Association. Ss: number of substrates attached by each species, Loc: number of localities where they were observed. Seaweeds: rate of seaweeds in substrates attached by each species. Solitary: rate of substrates which each species is solitarily encrusting.

Species	Ss	Loc	Seaweeds	Solitary
* <i>Celleporina porosissima</i> Harmer	252	29	.38	.31
<i>Cauloramphus spiniferum</i> (Johnston)	173	27	.01	.34
* <i>Celleporella hyalina</i> (Linnaeus)	120	19	.50	.12
* <i>Watersipora aterrima</i> (Ortmann)	87	20	.28	.19
* <i>Escharoides jacksoni</i> (Waters)	71	21	.24	.09
* <i>Smittoidea prolifica</i> Osburn	71	24	.07	.12
<i>Rhynchozoon</i> sp.	70	20	.01	.11
<i>Celleporaria aperta</i> (Hincks)	60	14	.08	.15
* <i>Fenestrulina malusii</i> (Audouin)	59	21	.21	.07
* <i>Exochella longirostris</i> Jullien	58	20	.14	.11
<i>Schizomavella auriculata</i> (Hassall)	47	15	.02	.02
<i>Microporella californica</i> (Busk)	43	10		.13
* <i>M. ciliata</i> (Pallas)	37	12	.56	.03
* <i>Reginella furcata</i> (Hincks)	33	7		.06
<i>Lepraliella biporosa</i> sp. nov.	33	7		.10
<i>Cryptosula pallasiana</i> (Moll)	30	5		.36
<i>Electra crustulenta</i> (Pallas)	22	14	.18	.09
<i>Membranipora serrilamella</i> Osburn	17	8		.71
<i>Phylactella</i> (?) sp.	15	8		.14
<i>Calyptotheca parcimunita</i> Harmer	11	7		.09
<i>Schizoporella</i> sp.	11	4		.18
<i>Thalamoporella lioticha</i> (Ortmann)	10	4	1.00	
<i>Hippothoa flagellum</i> Manzoni	10	5	.30	
* <i>Parasmittina unispinosa</i> (Waters)	9	5		
<i>Conopeum</i> sp.	9	6		.33
<i>Parasmittina tropica</i> (Waters)	8	1		
<i>Porella porifera</i> (Hincks)	8	4		.12
<i>Electra angulata</i> Levinsen	7	6		.43
<i>Pleurocodonellina signata</i> (Waters)	7	5		.28
* <i>Membranipora savartii</i> (Audouin)	6	5		.33
<i>Eurystomella bilabiata</i> (Hincks)	4	3		
<i>Schizoporella unicornis</i> (Johnston)	1	1		1.00
<i>Aimulosia aculeata</i> Canu and Bassler	1	1		1.00
<i>Parasmittina</i> sp. B	1	1		
<i>Tricellaria occidentalis</i> (Trask)	20	6	.73	.10
<i>Bugula californica</i> Robertson	6	3		.50
* <i>Caberea lata</i> Busk	1	1		

in this association. *Membranipora savartii*, *Chaperia acanthina*, *Watersipora aterrima*, *Mucropetraliella philippinensis*, *Codonellina montferrandii*, *Smittoidea prolifica*, *Parasmittina unispinosa* and *Celleporina radiata* are tropical to subtropical. *Reginella furcata*, *Celleporella hyalina* and *Escharoides jacksoni* are boreal to subboreal. *Microporella ciliata* and *Fenestrulina malusii* are cosmopolitan. *Exochella longirostris* is widely distributed except in the arctic region. *Cryptosula reticulata* and *Celleporina porosissima*

live only around the Japanese Islands.

5. The *Aimulosia aculeata* Association

Unilaminar encrusting colonies: *Parasmittina tropica*, *Parasmittina* sp. B, *Lepraliella biporosa*, *Aimulosia aculeata*, *Phylactella* sp.

These species are mainly found from Facies V. They usually attach only to the sheltered surface within molluscan shells.

Parasmittina tropica is tropical to subtropical. *Parasmittina* sp. B and *Lepraliella biporosa* seem

to be local Japanese species. The zoogeographical character of this association is indistinct.

6. *Osthimosia multiavicularia*, *Tegella unicornis* and *Smittoidea pacifica*

These three species cannot be classified into the above five associations because they show no clear peak of abundance in any of the sedimentary facies.

Discussion

1. Frequency of bryozoan fragments

Bryozoan fragments were numerous in the sediments of Facies II and few in those of Facies V and VI (Table 1).

The maximum frequency, 1093 fragments per 100 g of sediments, was observed in the middle part of the shell bed at Nishiyatsu. The abundance and well preservation of the fossils of sessile animals may reflect the richness of suitable substrates and the low rate of sedimentation in the non-deltaic shelf environment. Actually such a concentration of bryozoan fragments was also observed in the Holocene non-deltaic shelf deposits east of the Boso Peninsula (Arakawa, 1984).

Bryozoans in Facies V were attached only to the sheltered surface of molluscan shells. Such "interstitial bryozoans" have been observed in a high energy environment where larvae must be protected from abrasion (Håkansson and Winston, 1985). Cross-stratification and rounded molluscan shells suggest that the limited colonization of bryozoans in Facies V also resulted from strong waves and currents. On the other hand, all of the bryozoan fragments in Facies VI were separated from substrates, so the factor which caused the rareness of bryozoans in Facies VI cannot be assumed without a comparison with other characteristics of the bryozoan fauna.

2. Relation to substrates

All fragments of erect rigid colonies were separated from substrates, but it is believed that most of them attach only to hard substrates. The "sand fauna" bryozoans can attach to small substrates such as sand grains, as stated above.

The encrusting bryozoan colonies in Facies I,

II and III were usually attached to molluscan shells. The "interstitial bryozoans" of Facies V were attached only to the sheltered surface of molluscan shells. They are the post-mortem epizoans of molluscs. Stones are one of the important substrates in Facies II and III. Bryozoans also encrusted solitary corals in Facies I and barnacles in Facies II. Colonies encrusting other bryozoans were also observed frequently in Facies II. This fact also suggests the low rate of sedimentation in Facies II.

In contrast with Facies I, II, III and V, most of the encrusting colonies were separated from substrates in Facies IV and VI. Only six species, *Celleporella hyalina*, *Celleporina porosissima*, *Reginella furcata*, *Escharoides jacksoni*, *Fenestrulina malusii* and *Lepraliella biporosa* encrusted molluscan shells in Facies IV. No encrusting bryozoans were observed on the shells of the *Callithaca-Patinopecten* Assemblage (Aoki and Baba, 1980) in Facies VI. This type of bryozoan remains are regarded as an inflow into the environment around the molluscan habitats. The substrates of these bryozoans cannot be determined, but there is a possibility that some of them were soft substrates, such as seaweeds. Actually, ten species of these bryozoans were observed as epiphytes on the Pacific coast of the Kanto region (Table 2). Most of the seven species from Facies VI are included in them. Therefore, the rareness of bryozoans in Facies VI can probably be attributed to the restricted availability of substrates.

3. Relative species richness of each association

The relative species richness of each association was compared in each facies (Table 3). It is expressed as

$$r_i = 100n_i/N$$

where n_i is the number of species of each association in Facies i and where N is the total number of species in Facies i . *Cellaria*, *Conescharrellina*, *Flabellopora* and *Sertella* were each treated as one species because they include many indeterminate fragments.

The *Cellaria punctata-Thalamoporella novae-hollandiae* Association and the *Myriozoum serratum-Microporella californica* Association

Table 3. Facies-related distribution of five bryozoan associations and other characteristics of bryozoan fauna in the Jizodo Formation. A: abundant ($40\% \leq r_i$), C: common ($20\% \leq r_i < 40\%$), ++: rare ($10\% \leq r_i < 20\%$), +: very rare ($0\% < r_i < 10\%$).

	Facies					
	I	II	III	IV	V	VI
<i>Cellaria-Thalamoporella</i>	A	++	++	++		
<i>Myriozoum-Microporella</i>	C	C	++	++	++	++
<i>Verminaria-Hippoporina</i>	C	++	C	++	++	C
<i>Celleporella-Watersipora</i>	+	C	C	A	C	A
<i>Aimulosia</i>	+	+	+	+	C	
Frequency of bryozoan fragments	—	numerous	—	—	few	few
Relation between encrusting species and molluscan shells	post-mortem epizoans for molluscs	post-mortem epizoans for molluscs	post-mortem epizoans for molluscs	separated	post-mortem epizoans (interstitial)	separated
Other substrates	corals	other bryozoans, stones, barnacles	stones	epiphytes?	—	epiphytes?
Zoarial forms	rooted, free-living or erect rigid	all forms abundant	mainly encrusting	mainly encrusting	only encrusting	only encrusting

ranked highly only in shelf sand facies (Facies I and II). The *Cellaria-Thalamoporella* Association, especially, was not distributed in bay mouth deposits (Facies V and VI). Many species in this association may have been comparatively stenotopic to environmental factors, such as water movements, substrates, temperature and salinity.

On the contrary, the *Celleporella hyalina-Watersipora atterima* Association was relatively rich in all samples except Facies I. It is known that most of the bryozoans living in the littoral zone are not exclusively littoral. Moreover, their fragments are easily transported to deeper places by storm-generated currents.

4. Zoarial forms

Concerning the distribution of zoarial forms, a few studies have led to some possible conclusions using so-called Q-mode approaches that utilize a number of fragments (e.g., Lagaaij and Gautier, 1965). In the case of the Jizodo Formation, rooted and jointed colonies (mainly *Cellaria*) made up more than 50% of bryozoan fragments in Facies I, and encrusting colonies re-

placed them in other facies. The proportion of zoarial forms among the fragments in Facies I resembles the "distal fluvio-marine fan" assemblages of Lagaaij and Gautier (1965). It is an empirical fact that the predominance of cellariforms seems to indicate a high rate of sedimentation, but there is no evidence of circumdeltaic deposits for Facies I.

The quantity r_i defined above can also be applied to zoarial forms. For both erect rigid species and "sand fauna" species, the value of r_i is greatest in Facies I. Encrusting species show a value of r_i greater than 50% in all facies, and 100% in facies V and VI. Such an extreme composition of zoarial forms corresponds to the rareness of fragments which may have resulted from the severity of stresses caused by environmental factors, as discussed above.

Palaeontological Descriptions

Order Cheilostomata Busk, 1852
 Suborder Ascophora Levinsen, 1909
 Family Exochellidae Bassler, 1935
 Genus *Escharoides* Milne-Edwards, 1836

***Escharoides jacksoni* (Waters)**

Fig. 4A

Smittia jacksoni Waters, 1900, p. 87, pl. 12, fig. 18.

Escharoides jacksoni: Kluge, 1962, pp. 568–569, figs. 401, 402.

Specimens. CBM-PI-0001403, 1404 from Nishiyatsu.

Measurements (in mm).

	Length	Width
Zooecia	0.73–0.92	0.53–0.82
Orifices	0.20–0.22	0.20–0.23
Avicularia	0.23–0.33	0.08–0.17
Ovicells	0.44–0.56	0.35–0.44

Occurrence. Hogisaku, Oi, Nishiyatsu, Ichinosawa, west of Nanamagari, Myoko and Kawazai.

Distribution. Greenland, Alaska, the Arctic Ocean of the USSR and Japan.

Family Watersiporidae Vigneaux, 1949

Genus *Watersipora* Neviani, 1895

***Watersipora aterrima* (Ortmann)**

Figs. 4C, D

Schizoporella aterrima Ortmann, 1890, p. 49, pl. 3, fig. 36.

Watersipora cucullata watersi Mawatari, 1952a, pp. 14–17; Mawatari, 1952b, p. 285.

Dakaria subovoidea: Harmer, 1957, pp. 1022–1024, pl. 69, figs. 11, 12, 14, text-fig. 111. (*partim*; nec *Cellepora subovoidea* d'Orbigny, 1852)

Watersipora subovoidea: Long and Rucker, 1969, p. 63, fig. 5–4. (sensu Harmer, 1957; nec *Cellepora subovoidea* d'Orbigny, 1852)

Watersipora aterrima: Soule and Soule, 1974, pp. 307–308, pl. 3, fig. 6.

Specimens. CBM-PI-0001405, 1406 from Kawazai.

Measurements (in mm).

	Length	Width
Zooecia	0.78–1.04	0.42–0.58
Orifices	0.19–0.26	0.25–0.31

Remarks. Harmer (1957) placed four watersi-

porids, *Cellepora subtorquata* d'Orbigny, *Lepralia cucullata* Busk, *L. atrofusca* Busk and *Schizoporella aterrima* Ortmann, in synonymy under *Cellepora subovoidea* d'Orbigny. Since then, the name *Watersipora subovoidea* has been applied to them in Japan. As pointed out by Soule and Soule (1974), however, the "*W. subovoidea*" of Harmer can be divided into some species such as *W. subtorquata* and *W. aterrima*. The specimens from the Jizodo Formation and the "*W. subovoidea*" living in the Kanto region is identified as *W. aterrima* which is characterized by a wider sinus, small cardelles and large frontal pores. The proximal-side of the orifice is occasionally elevated and thickened in Japanese specimens like *W. cucullata* and *W. subtorquata*.

Occurrence. Nishiyatsu, Ichinosawa, Kawazai and the Nagara-dam.

Distribution. Torres Straits, Hawaii and Japan. This species is probably widespread in the Indo-Pacific area (Soule and Soule, 1974).

Family Cryptosulidae Vigneaux, 1949

Genus *Cryptosula* Canu and Bassler, 1925

***Cryptosula reticulata* (Okada), comb. nov.**

Figs. 5A, B

Lepralia reticulata Okada, 1929, p. 24, pl. 5, figs. 4, 5; Androsova, 1958, p. 128, text-fig. 46.

"*Lepralia*" *reticulata*: Hayami, 1975, p. 122, pl. 13, fig. 3.

Cryptosula pallasiana: Hayami, 1975, p. 88, pl. 19, fig. 5 (only listed and illustrated); Nishizawa, 1990, p. 120, pl. 5, fig. 1. (nec *Eschara pallasiana* Moll, 1803)

Specimens. CBM-PI-0001407, 1408 from Kawazai.

Emended diagnosis. *Cryptosula* with a horse-shoe shaped orifice. Suboral avicularia present, sometimes elongated. Peristome not raised.

Measurements (in mm).

	Length	Width
Zooecia	0.59–0.67	0.22–0.26
Orifices	0.16–0.19	0.16–0.20
Avicularia*	0.04	0.02

* Elongate avicularia

Remarks. Okada (1929) and Androsova

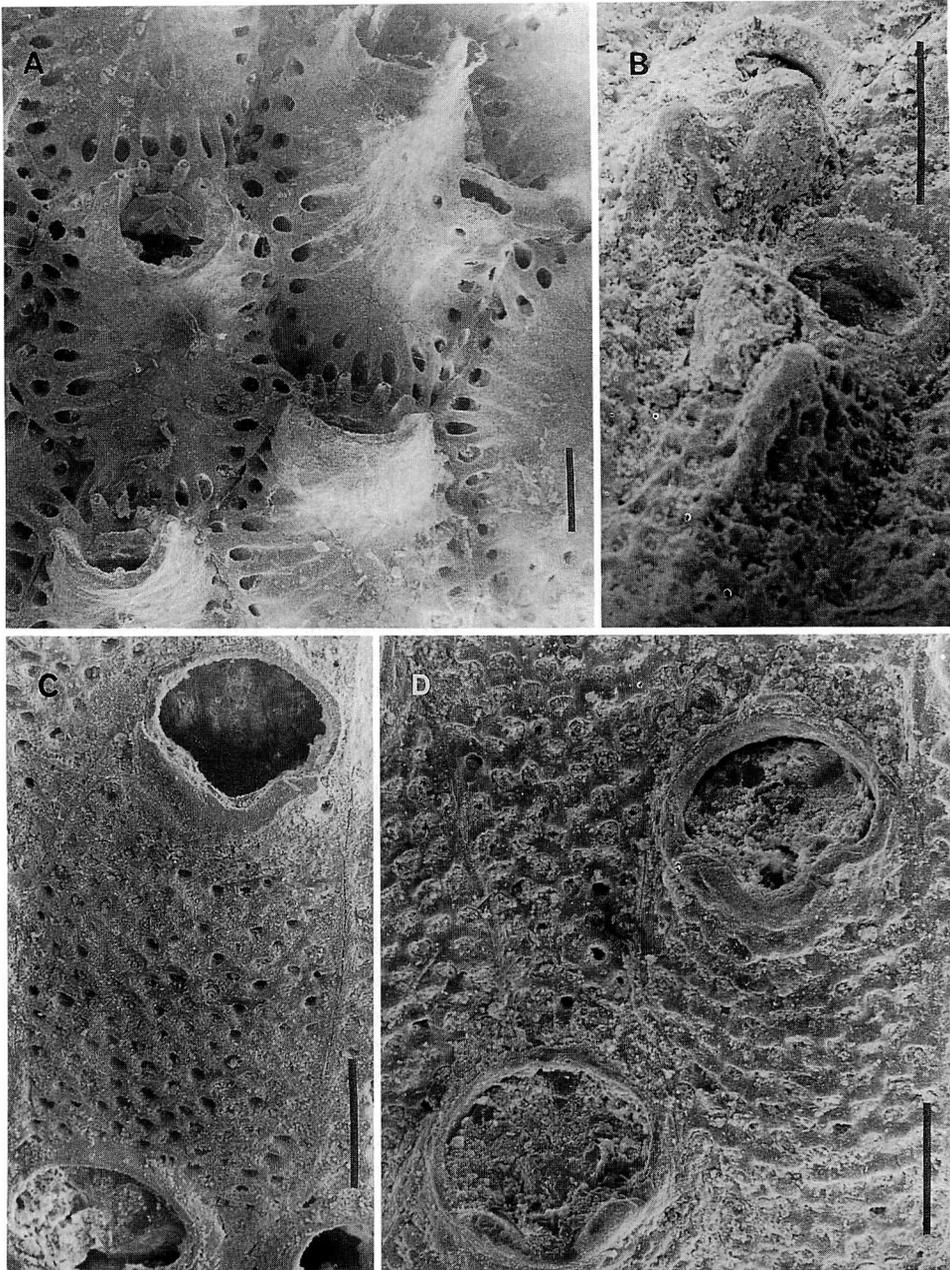


Fig. 4. A. *Escharoides jacksoni* (Waters). B. *Schizoporella* sp. with a prominent umbo. C, D. *Watersipora aterrima* (Ortmann). C. General morphotype, orificial collar not developed. D. Morphotype with a peristome elevated and thickened proximally. All scale bars show 200 μ .

(1958) described that avicularia are wanting in this species. However, Hayami's (1975) material (IGPS 92231 of Tohoku University) and the present specimens have a small suboral avicularium on a pointed umbo. Considering that the suboral avicularium is inconstant in *Crypt-*

osula pallasiana (Moll), the difference among them is regarded as the polymorphism of one species.

This species differs from *C. pallasiana* in the smaller poster of the orifice and in the presence of elongated suboral avicularium. Hayami

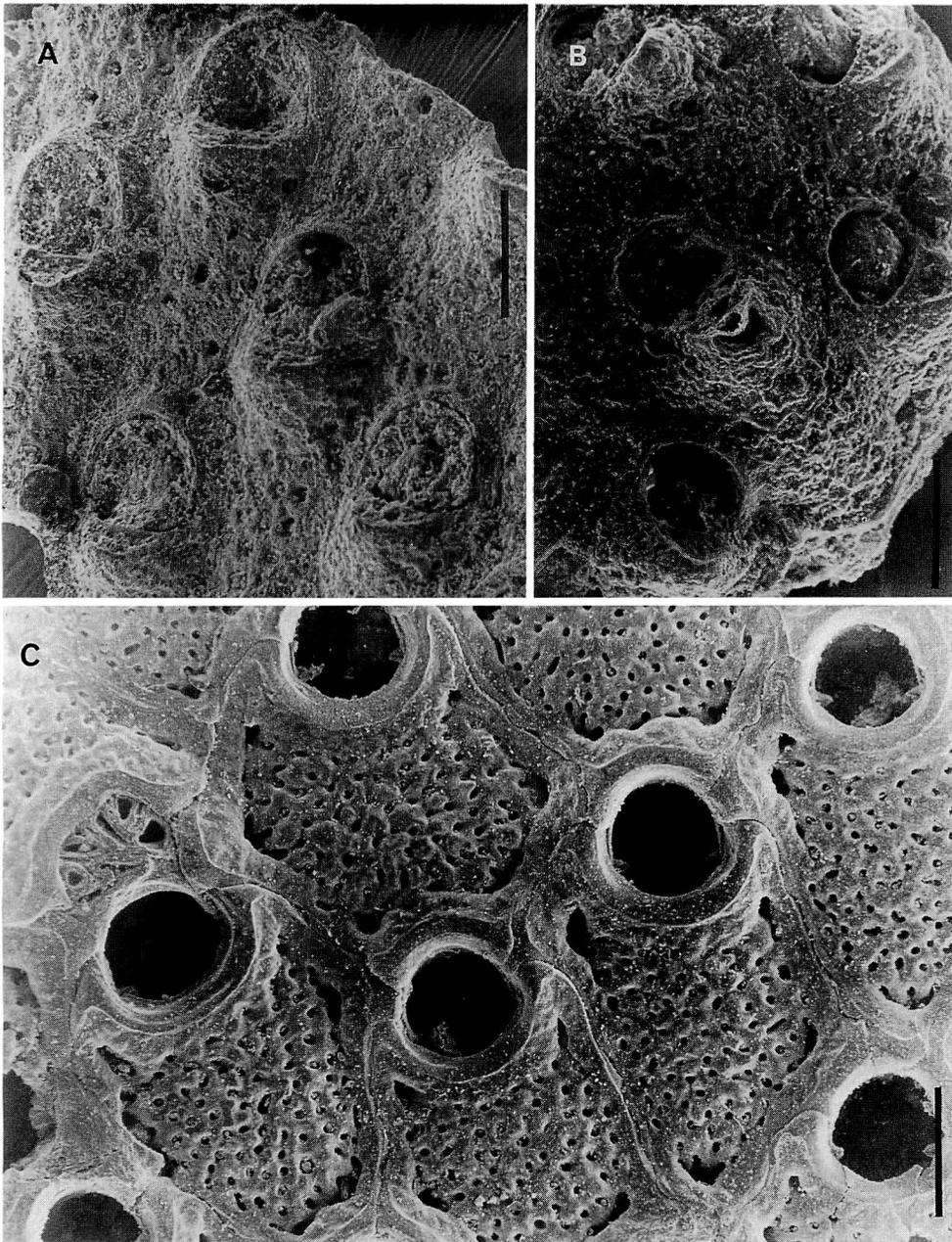


Fig. 5. A, B. *Cryptosula reticulata* (Okada). A. General morphotype with a suboral depression. B. Zooid with an elongated avicularium. C. *Hippoporina purpurata* sp. nov. characterized by a circular orifice, large oocelial pores and a rim surrounding its frontal wall, primary orifice and ovicell.

(1975) and Nishizawa (1990) reported *C. pallasiانا* from the Pliocene to Pleistocene deposits of Northern Japan, but its orifices are not bell-shaped. So it may be identical with *C. reticulata*.

Occurrence. Nishiyatsu and Kawazai.

Distribution. Japan Sea and the Pacific coast of Japan (Takahagi, Ibaraki Prefecture).

Family Porinidae d'Orbigny, 1852
Genus *Haswellina* Livingstone, 1928

***Haswellina* (?) sp.**

Fig. 12C

Specimens. CBM-PI-0001409 from Yatsu and CBM-PI-0001410 from Yamadakubo.

Description. Zoarium erect, cylindrical, separated from the substrates. Zooecia elongated, zooecial boundary indistinct. Frontal almost smooth, but small frontal pores and areolae scattered. Primary orifice immersed in a tubular peristome. Avicularia rarely present, small, rounded. Spiramen immersed, indistinct. Ovicell not found.

Measurements (in mm).

	Length	Width
Zooecia	1.03–1.08	0.43–0.50
Orifices*	0.18–0.20	0.21–0.23
Avicularia	0.06–0.09	0.05–0.07

* Secondary orifice

Remarks. This species is indeterminable because of its ill-preservation. It resembles the thickly calcified part of a colony of *Tessardoma boreale* (Busk) in its immersed spiramen (see Cheetham and Cook, 1983), but the presence of frontal pores is applicable to the genus *Haswellina*. A specimen with a projecting spiramen has not been found yet.

Occurrence. Yatsu, Nishiyatsu, Ichinosawa, the Nanamagari Shrine, Atebi, Jizodo and Yamadakubo.

Family Hippopodiniidae Levinsen, 1909

Genus *Hippoporina* Neviani, 1895***Hippoporina purpurata* sp. nov.**

Fig. 5C

Specimens. Holotype, CBM-PI-0001411 from Nishiyatsu. Paratype, CBM-PI-0001412 from Nishiyatsu.

Diagnosis. Zoarium encrusting shells or gravels, generally unilaminar, often showing the spiral growth, purple in color. Zooecia hexagonal, flat, separated by a raised rim. Frontal perforated by tremopores, covered by the coarse, nodular calcification, with a few of areolar pores in the corners. Primary orifice with a pair of blunt lateral cardelles, proximal border of a wide poster forming the same circles as an anter; raised rim also developed

around the orifice. No avicularium. Two pores on the transverse wall and two to three pores on each lateral wall. Ovicell immersed, surrounded disto-laterally by a raised rim, with large and irregular pores.

Measurements (in mm).

	Length	Width
Zooecia	0.57–0.73	0.36–0.63
Orifices	0.16–0.18	0.15–0.20
Ovicells	0.18	0.26

Remarks. This species resembles a few of species in the genus *Dakaria* Jullien, such as *D. sertata* Canu and Bassler and *D. apertura* Osburn, in its widely sinuated orifice and in the secondary calcification surrounding orifices or ovicells (Canu and Bassler, 1930; Osburn, 1952). However, the poster of the orifice of this species is not a U-shaped sinus, so this species cannot be placed in the family Schizoporellidae Jullien including the genus *Dakaria*. The shape of the orifice shows that this species belongs to the family Hippopodiniidae Levinsen. This species may be immediate to *Hippoporina epaxia* Goron because both species have no avicularium (Gordon, 1984).

The purple color of the frontal wall is one of the characteristics of this species. This species is distinguishable by the naked eye because of its color. The species name is derived from this color.

Occurrence. Oi, Nishiyatsu and the Nagaramdam.

Distribution. Tateyama, the southern tip of the Boso Peninsula.

Family Schizoporellidae Jullien, 1903

Genus *Schizoporella* Hincks, 1877***Schizoporella* sp.**

Fig. 4B

Specimens. CBM-PI-0001413 from Kawazai.

Description. Zoarium encrusting, separated from substates. Zooecia quadrate to hexagonal, somewhat convex, separated by a furrow. Frontal thick, finely perforated, with a conical umbo proximal to the sinus. Primary orifice wider than long, anter semicircular, with wide and shallow sinus. Avicularia typically single,

occasionally paired, situated lateral to the orifice, rostrum pointed, directed distally.

Measurements (in mm).

	Length	Width
Zooecia	0.61-0.68	0.31-0.33
Orifices	0.12-0.15	0.16-0.19
Avicularia	0.11-0.13	0.04-0.06

Remarks. This species is characterized by a conical umbo proximal to the sinus, but the same projection is observed in many species of *Schizoporella* (e.g., *S. unicornis*). This species is indeterminable because its ovicell has not been found yet.

Occurrence. Kawazai.

Genus *Buffonellodes* Strand, 1928

***Buffonellodes granulosa* (Sakakura),**

comb. nov.

Fig. 6A

Lacerna granulosa Sakakura, 1935b, pp. 22-23, pl. 4, figs. 2, 5; Kataoka, 1961, p.217, pl. 33, fig. 7 (only listed and illustrated).

Specimens. CBM-PI-0001414 from Jizodo.

Emended diagnosis. *Buffonellodes* characterized by much inflated zooecia and conspicuous frontal granulation. Primary orifice with narrow sinus.

Measurements (in mm).

	Length	Width
Zooecia	0.56-0.60	0.42-0.60
Orifices	0.14-0.17	0.14-0.18
Avicularia	0.07-0.10	0.04-0.06
Ovicells	0.43-0.44	0.53-0.56

Remarks. As pointed out by Gordon (1984), the schizoporellids with a median avicularium and an imperforate frontal wall have been placed in the genus *Lacerna* Jullien, following Canu and Bassler (1920). He concluded that *Lacerna* and *Buffonellodes* are distinct genera and that aviculiferous species belong to the latter. I think that the presence or absence of avicularium is important in the differentiation of ascophoran genera (see the discussion in *Aimulosia* and *Cyclocolpota*), although their evolution also needs to be studied more. Therefore, this species is placed in *Buffonellodes* on

the basis of the presence of suboral avicularia.

Occurrence. Jizodo.

Distribution. This species has been found only from Japanese Pleistocene deposits. However, Kataoka's materials were collected from the Ryukyu Limestone deposited under the reflection of the Kuroshio, so this species may have lived in the warmer region of the Japanese Islands.

Family Smittinidae Levinsen, 1909

Genus *Smittoidea* Osburn, 1952

***Smittoidea pacifica* Soule et Soule**

Fig. 6B

Smittoidea reticulata ascoporoides Sakakura, 1935 b, p. 27, pl. 5, fig. 4.

Smittoidea reticulata ascoporoides: Kataoka, 1961, p. 261, pl. 36, fig. 9.

Smittoidea reticulata: Osburn, 1952, pp. 409-410, pl. 48, figs. 9, 10. (*partim*; nec *Smiittia reticulata* MacGillivray, 1842)

Smittoidea pacifica Soule et Soule, 1973, pp. 380-382, figs. 1E-H.

Specimens. CBM-PI-0001415 from Oi.

Measurements (in mm).

	Length	Width
Zooecia	0.48-0.54	0.27-0.37
Orifices	0.13-0.17	0.13-0.16
Avicularia	0.13-0.16	0.07-0.08
Ovicells	0.63	0.70

Remarks. The presence of *Smittoidea reticulata* (MacGillivray) in the Indo-Pacific region was doubted by Harmer (1957), Soule and Soule (1973), and Hayward and Ryland (1979). It is clear that *S. reticulata* var. *ascoporoides* (Sakakura) differs from *S. reticulata* (s.l.) in the disappearance of interareolar ridges by the secondary calcification.

Soule and Soule identified Osburn's materials of *S. reticulata* from the Galapagos Islands and Hawaii as the new species *S. pacifica*. They established this species on the basis of its rareness of "reticulation", its much narrowed rostral tip and its complete ooecial peristome. These features are perfectly applicable to *S. reticulata* var. *ascoporoides*. Sakakura's species differs from *S. pacifica* only in the peristomial

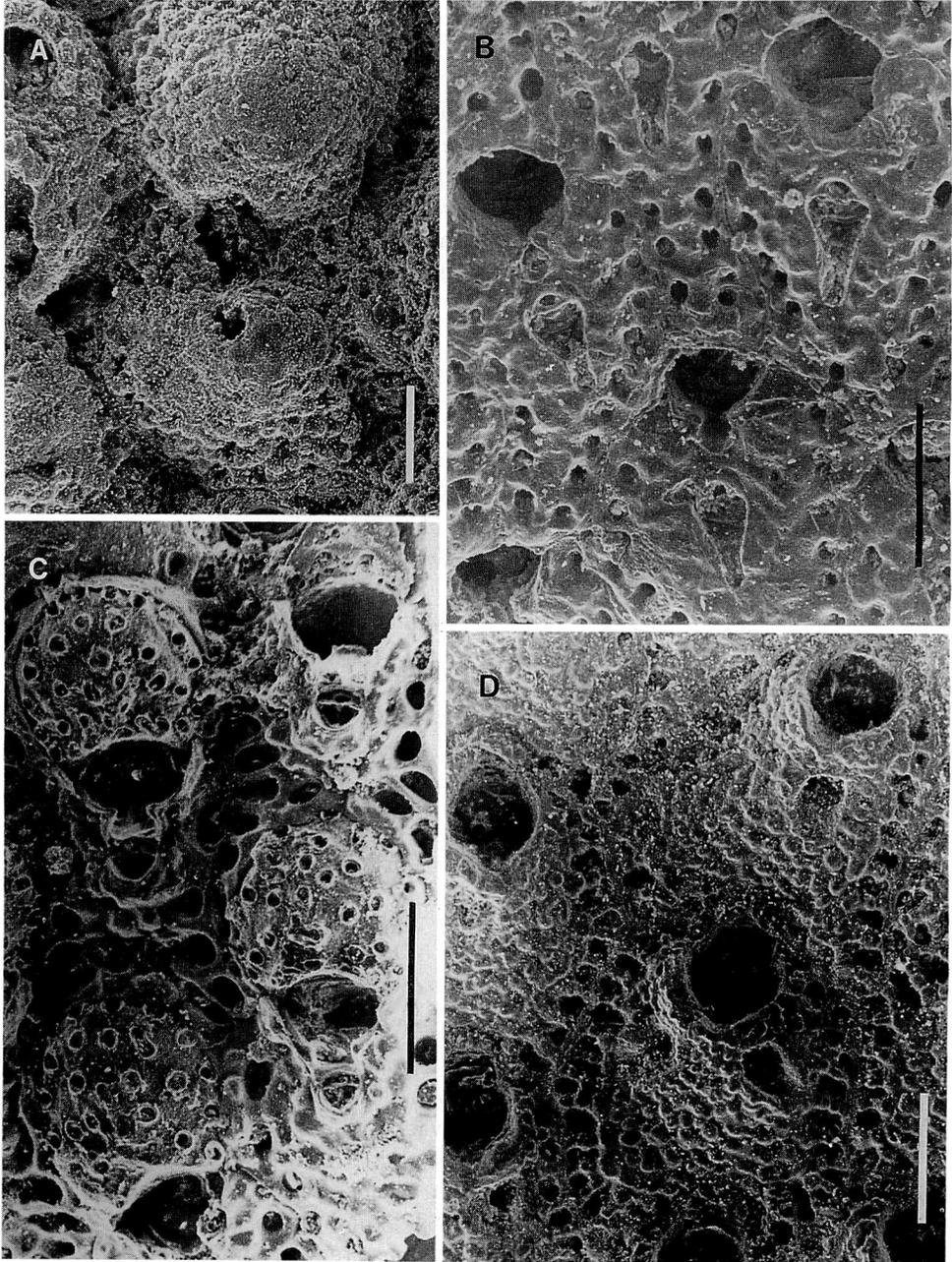


Fig. 6. A. *Buffonellodes granulosa* (Sakakura). B. *Smittoidea pacifica* Soule and Soule. The left zooid has a peristomial pore. C. *Smittoidea prolifica* Osburn, suboral avicularia with a short lingula. D. *Parasmittina tropica* (Waters).

pore which is originated from the proximal sinus of the peristome and which is inconstant even in one colony. Thus these two species are synonymous with each other.

Occurrence. Oi, Nishiyatsu, the Nanamagari Shrine, Atebi, Jizodo, Myoko, Kawazai and the

Nagara-dam.

Distribution. The Galapagos Islands, Hawaii and Japan. According to Soule and Soule (1973), *Smittina reticulata* from the Philippine Islands (Canu and Bassler, 1929) is quite similar to this species.

***Smittoidea prolifica* Osburn**

Fig. 6C

Smittoidea prolifica Osburn, 1952, pp. 408–409, pl. 78, figs. 7, 8; Long and Rucker, 1969, p. 63, fig. 4–2; Hayami, 1975, p. 89, pl. 16, fig. 7 (only listed and illustrated).

Smittina levis: Harmer, 1957, pp. 919–921, pl. 63, figs. 1–5. (*partim*; nec *Smittia levis* Kirkpatrick, 1890)

Smittoidea notoensis Hayami, 1975, pp. 114–115, pl. 16, fig. 8.

Specimens. CBM-PI-0001416 from Kawazai.

Measurements (in mm).

	Length	Width
Zooecia	0.35–0.49	0.18–0.28
Orifices	0.08–0.10	0.08–0.13
Avicularia	0.04–0.06	0.05–0.06
Ovicells	0.20–0.25	0.20–0.23

Remarks. The present specimens are correspondent to the type of rounded avicularium of *Smittina levis* (Kirkpatrick) reported by Harmer (1957). Gordon (1984) pointed that it differs from *S. levis* s.s. in lacking a long acute avicularian mandible. He reported *Smittoidea zealandiae* (Brown) as one of “*S. levis* with rounded avicularium”, but the present specimens differs in the absence of additional pores on the base of peristome. *Smittia landsborovii* (Johnston) in Ortmann (1890) is conspecific with *Smittoidea zealandiae* in this point.

The specimens from the Jizodo Formation occasionally show the pectinate ridge along the distal edge of the orifice, which is also observed in the type specimen of *S. levis* (Soule and Soule, 1973). The presence of lingula on the hinge bar of avicularium is remarkable. The features of the avicularium are similar to Harmer’s materials.

Smittoidea notoensis Hayami from the Pliocene to Pleistocene deposits of Northern Japan is the synonym of this species. She differentiated it from *S. prolifica* Osburn on the basis of the absence of a large avicularian chamber, the nature of the ovicell process and the presence of a sinus, but these are not conspicuous differences. I confirmed that the type specimen of *S.*

notoensis (IGPS 92182 of Tohoku University) coincides with the specimens from the Jizodo Formation on all points except for the absence of a large avicularian chamber.

Occurrence. Owada, Ichinosawa and Kawazai.

Distribution. California, Torres Straits and Japan.

Genus *Parasmittina* Osburn, 1952

***Parasmittina tropica* (Waters)**

Fig. 6D

Smittina tropica Waters, 1909, p. 174, pl. 17, figs. 10–14.

Smittina tropica: Harmer, 1957, pp. 934–937, pl. 64, figs. 23–28.

Parasmittina tropica: Powell, 1967, p. 172, pl. 3, fig. 14; Cook, 1968, p. 215; Hayward, 1974, p. 384; Gordon, 1984, p. 96, pl. 35, fig. D.

Specimens. CBM-PI-0001417 from Owada.

Measurements (in mm).

	Length	Width
Zooecia	0.43–0.57	0.28–0.47
Orifices	0.09–0.14	0.11–0.14
Avicularia	0.08–0.11	0.03–0.07
Ovicells	0.19–0.21	0.26–0.29

Occurrence. Owada, Hogisaku, Yatsu, Oi, Nishiyatsu and Jizodo.

Distribution. West Africa, the Aegean Sea, the Red Sea, the Indian Ocean and the Western Pacific.

Parasmittina cf. parsevaliformis

Soule et Soule

Fig. 7A

Smittina trispinosa nitida: Sakakura, 1935b, p. 27, pl. 5, fig. 5. (sensu Canu and Bassler, 1929; nec *Discopora trispinosa* Johnston, 1825; nec *Discopora nitida* Verrill, 1875)

Smittina raigii: Harmer, 1957, p. 65, figs. 1–3. (*partim*; nec *Cellepora raigii* Audouin, 1826)

Parasmittina trispinosa nitida: Kataoka, 1961, p. 259, pl. 34, fig. 9. (sensu Sakakura, 1935b; nec *Discopora trispinosa* Johnston, 1825; nec *Discopora nitida* Verrill, 1875)

Compare.

Parasmittina parsevaliformis Soule and Soule,

1973, pp. 411–414, figs. 8A–F.

Specimens. CBM-PI-0001418 from Nishiyatsu.

Description. Zoarium encrusting shells and stones. Zooecia oblong to hexagonal, separated by a thread. Frontal granulated, with small areolar pores. Primary orifice round, bisinuate, lyrula wide and anvil-shaped, cardelles pointed. Secondary orifice round or pyriform, with two spines. Small avicularia situated lateral or proximal to the orifice, pointed or spatulate, directed distally in many cases. Spatulate avicularia sometimes elongated to the proximal end of frontal wall. Ovicell globular, surrounded by secondary calcification, perforated by small pores, or rarely by irregularly shaped fissures.

Measurements (in mm).

	Length	Width
Zooecia	0.46–0.61	0.26–0.36
Orifices	0.08–0.11	0.09–0.11
Avicularia	0.05–0.13	0.03–0.05
Ovicells	0.13–0.15	0.15–0.20

Remarks. Sakakura's *Smittina trispinosa* is based on the descriptions of its variations in Canu and Bassler (1929). However, it is doubtful that any of the western Pacific parasmitinid is identified with *S. trispinosa* (Harmer, 1957; Soule and Soule, 1973). Harmer included Sakakura's *S. trispinosa nitida* in his *S. raigii*, but the Japanese species does not have a large triangular avicularia directed distally.

On the other hand, Canu and Bassler's specimens labeled as *S. trispinosa* var. *nitida* Hincks were examined by Soule and Soule. According to their report (Soule and Soule, 1973), those specimens include two or more species which resemble *Parasmittina decorata* Soule and Soule, *P. delicatula* (Busk) and *P. obstructa* (Waters). Compared with Japanese species, *P. delicatula* and *P. obstructa* differs in the large triangular avicularia. The Japanese species resembles *P. decorata* among them, but it is more similar to *P. parsevaliformis* Soule and Soule in the raised oral lappets and in the ovicell with few pores. However, a large spoon-shaped avicularium is not found in the Japanese species. It is also conspicuous that most of

the Japanese specimens have a single avicularia.

Occurrence. Yatsu, Oi, Nishiyatsu, the Nanamagari Shrine, Atebi, Jizodo, Yamadakubo, Myoko and Kawazai.

***Parasmittina* sp. A**

Fig. 7B

Specimens. CBM-PI-0001419 from Oi.

Description. Zoarium encrusting shells. Zooecia quadrate to hexagonal, somewhat elevated distally, separated by a thread. Frontal granulated, with a row of areolar pores. Primary orifice almost circular, bisinuate, lyrula wide and somewhat tapered, cardelles often not clear. Two spines rarely present. Peristome developed, with a proximal sinus. Large avicularium situated near the orifice, rostrum triangular, directed distally, encroaching on the peristome. Ovicell globular, somewhat immersed, perforated by large and irregular pores with rim, central area imperforate.

Measurements (in mm).

	Length	Width
Zooecia	0.40–0.63	0.26–0.48
Orifices	0.07–0.11	0.09–0.11
Avicularia	0.14–0.15	0.07–0.09
Ovicells	0.15–0.20	0.20–0.28

Remarks. This species resembles *Parasmittina collifera* (Robertson) in the triangular avicularia directed distally, the sinuate peristome and the ovicell with several large pores which vary in size, form and disposition (Osburn, 1952), but it does not have conspicuous frontal nodules. The development of peristome is similar to *P. tropica* (Waters), but a sinus of the secondary orifice is narrower. This species also resembles *P. hastingsae* Soule and Soule, especially in the peristome with a narrow sinus, but differs in the situation of the avicularia encroaching on the peristome and in the features of the ovicells.

Occurrence. Owada, Hogisaku, Oi, Nishiyatsu, Atebi, Myoko, Kawazai and the Nagardam.

***Parasmittina* sp. B**

Fig. 7C

Specimens. CBM-PI-0001420 from Nishiya-

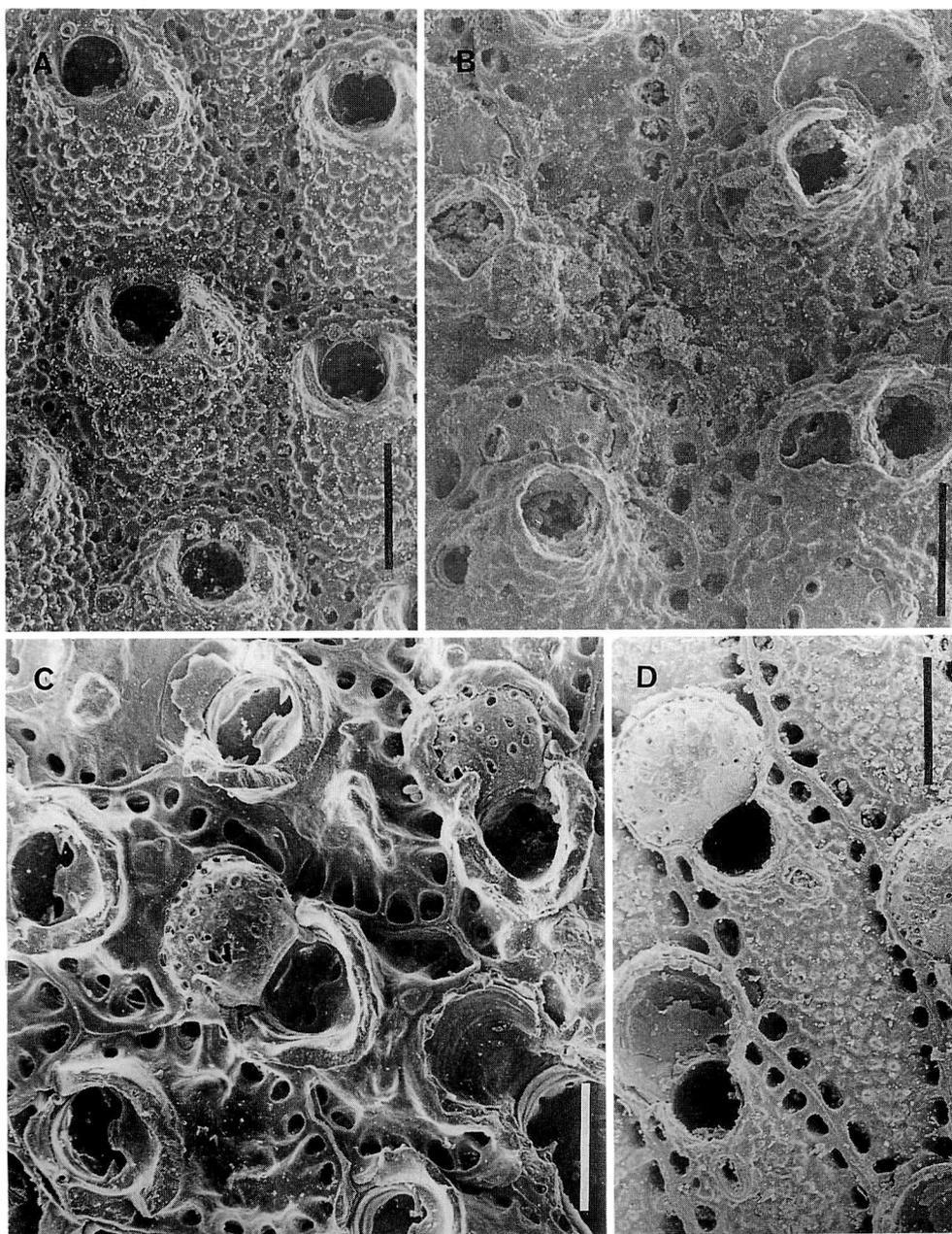


Fig. 7. A. *Parasmittina* cf. *parsevaliformis* Soule and Soule. B. *Parasmittina* sp. A characterized by an avicularium directed distally and an immersed ovicell with irregular pores. C. *Parasmittina* sp. B characterized by a very rough frontal wall and the absence of avicularia. D. *Pleurocodonellina signata* (Waters).

tsu.

Description. Zoarium encrusting shells. Zoecia hexagonal, distinct, separated by a little raised rim. Frontal imperforate, bearing knobs and ridges, with large marginal pores. Primary

orifice rounded, wider than long, bisinuate, with a wide lyrula. Peristome often developed, occasionally bearing a pair of stout spines on the distal position. No avicularium. Ovicell globular, wider than long, perforated by irregu-

lar pores.

Measurements (in mm).

	Length	Width
Zooecia	0.42–0.51	0.23–0.42
Orifices	0.09–0.10	0.09–0.14
Ovicells	0.16–0.22	0.24–0.26

Remarks. This species corresponds to the genus *Escharella* Gray in the bisinuate orifice and in the absence of avicularium. For example, it resembles *E. immersa* (Fleming) in the accentuated areolar pores (Hayward and Ryland, 1979). However, the ovicell of *Escharella* is imperforate, so this species may belong to some genus in the family Smittinidae. In this study, it is temporarily placed in the genus *Parasmittina* whose colonies sometimes include zooids without avicularia.

Occurrence. Owada, Nishiyatsu and the Nagara-dam.

Distribution. Hasaki Harbor, Ibaraki Prefecture.

Genus *Pleurocodonellina* Soule et Soule, 1973

***Pleurocodonellina signata* (Waters),**

comb. nov.

Fig. 7D

Smittia signata Waters, 1889, p. 3, pl. 3, figs. 4–6; Thornely, 1912, p. 151.

Lacerna signata: Canu and Bassler, 1929, p. 308, pl. 42, figs. 10, 11, text-fig. 131c, d; Sakakura, 1935b, p. 22.

Smittina signata: Hastings, 1932, p. 429, text-fig. 12d, e; Harmer, 1957, pp. 928–930, pl. 63, figs. 27–29.

Specimens. CBM-PI-0001421 from Nishiyatsu.

Emended diagnosis. *Pleurocodonellina* with a small poster. Zooecia oblong, elongated. Avicularium typically small, not median. Ovicell wider than long.

Measurements (in mm).

	Length	Width
Zooecia	0.52–0.86	0.28–0.43
Orifices	0.10–0.12	0.10–0.14
Avicularia	0.07–0.09	0.03–0.05
Ovicells	0.17–0.22	0.24–0.28

Remarks. Soule and Soule (1973) stated that this species might belong to their new genus *Pleurocodonellina*. The frontal wall of pleurocyst, the perforation of ovicells and the situation of frontal avicularium in this genus are the same as those in the genus *Parasmittina* Osburn, but *Pleurocodonellina* is different from *Parasmittina* in the absence of lyrula.

The identification of this species is also confused just like *Parasmittina trispinosa*, *Smittidea reticulata*, etc. Zooecia with paired avicularia reported by Harmer (1957) have not been observed in the specimens from the Jizodo Formation. Moreover, the development of cardelles is not constant even in the same colony.

Parasmittina signata (Waters) reported by Lagaaij (1963) and Winston and Håkansson (1986) is apparently different from the specimens from the Jizodo Formation in the development of a thick and scalloped peristomial collar.

Occurrence. Hogisaku, Oi, Nishiyatsu, Atebi and Jizodo.

Distribution. The Indo-Pacific province.

Family Microporellidae Hincks, 1880

Genus *Microporella* Hincks, 1877

***Microporella californica* (Busk)**

Figs. 8A, B

Lepralia californica Busk, 1856, p. 310, pl. 11, figs. 6, 7.

Microporella ciliata californica Hincks, 1883, p. 444, pl. 17, fig. 3.

Microporella californica: Canu and Bassler, 1923, p. 123, pl. 36, figs. 8–11; Osburn, 1952, pp. 381–382, pl. 44, fig. 2; Harmer, 1957, pp. 964–965; Soule, 1961, pp. 24–25.

Specimens. CBM-PI-0001422, 1423 from Nishiyatsu.

Measurements (in mm).

	Length	Width
Zooecia	0.52–0.72	0.31–0.48
Orifices	0.07–0.11	0.09–0.16
Avicularia	0.05–0.14	0.04–0.09
Ovicells	0.31–0.34	0.38–0.41

Remarks. The identification of four species, *M. californica* (Busk), *M. marsupiata* (Busk), *M.*

umbracula (Audouin) and *M. coronata* (Audouin), has been much confused.

Osburn (1952) regarded that *M. californica* differs from *M. marsupiata* in the larger frontal pores, the situation of median umbo and the more-developed radiating ribs of ovicells. However, Japanese specimens show the features of both these species. The frontal perforation by large pores is distinct in Japanese specimens, especially in the marginal part of colonies. The median umbo is generally surrounding an ascopore like *M. marsupiata* of Osburn (1952), but the umbo situated more proximally is also observed in the same colonies. The development of an oecial umbo is diverse among the specimens. *M. marsupiata* reported by Gordon (1984) also resembles two species in Osburn (1952), although its frontal wall is perforated by small pores.

On the other hand, *M. marsupiata* of the English Channel (Hayward and Ryland, 1979) differs evidently from Japanese specimens in the imperforate ovicell, the forked avicularia and the frontal perforation by small and scattered pores. Perhaps, *M. marsupiata* of Osburn (1952) may be identified as *M. californica*.

Harmer (1957), who pointed out that *Flustra coronata* and *F. umbracula* which were introduced by Audouin (1826) at the same time are synonymous with each other, seems to have regarded *M. californica* as the Pacific species and *M. umbracula* as the species distributed in the Atlantic Ocean to the Red Sea. According to him, *M. umbracula* has a personate ovicell and a pair of avicularia with long setiform mandibles. Osburn (1952) observed *M. coronata* from California, which is apparently the same as *M. umbracula* sensu Harmer (1957), and stated that *M. californica* differs from *M. coronata* in the coarser frontal wall, the in-hastate mandible and the pointed rostrum. Compared with *M. umbracula* from Florida (Winston, 1982; Winston and Håkansson, 1986), Japanese specimens differ in the pointed rostrum, although they show a close resemblance.

Gordon (1984) attached importance to the brown or black spine bases of these species. *M. californica* of California have black spine bases (Osburn, 1952). In the case of Japanese speci-

mens, this species occasionally has four to six long spines with brown bases.

Occurrence. Localities except for Yatsu, west of Nanamagari, Izumiyatsu, Ichinono and Yamadakubo.

Distribution. Vancouver to West of South America (Harmer, 1957). This species is also abundant on the Pacific coast of the Kanto region.

***Microporella cf. gibbosula* Canu et Bassler**
Figs. 8C, D

Compare.

Microporella gibbosula Canu et Bassler, 1930, pp. 20–21, pl. 3, figs. 1, 2; Osburn, 1952, p. 386, pl. 44, fig. 9; Soule, 1961, pp. 26–27.

Specimens. CBM-PI-0001424 from Jizodo.

Description. Zoarium encrusting shells. Zooecia hexagonal, somewhat convex, flat centrally, separated by a furrow. Frontal perforated by minute pores, finely granulated. Primary orifice semilunar, proximal border more or less concave. Peristome developed lateral to the orifice in ovicellate zooecia. Five to six oral spines present. Ascopore small, rounded, oblique. Avicularium single, situated on the lateral margin of zoecium, more proximal than the ascopore. Ovicell globular, wider than long, somewhat immersed, finely granulated.

Measurements (in mm).

	Length	Width
Zooecia	0.52–0.65	0.42–0.54
Orifices	0.07–0.08	0.10–0.13
Avicularia	0.07–0.09	0.05–0.07
Ovicells	0.20–0.23	0.29–0.32

Remarks. This species closely resembles *M. gibbosula* in the minute frontal perforation, the ascopore not surrounded by a rim and the situation of the avicularium. However, the present specimens show the development of a peristome lateral to the orifice, which was not observed in Canu and Bassler (1930) and Osburn (1952).

Occurrence. Jizodo.

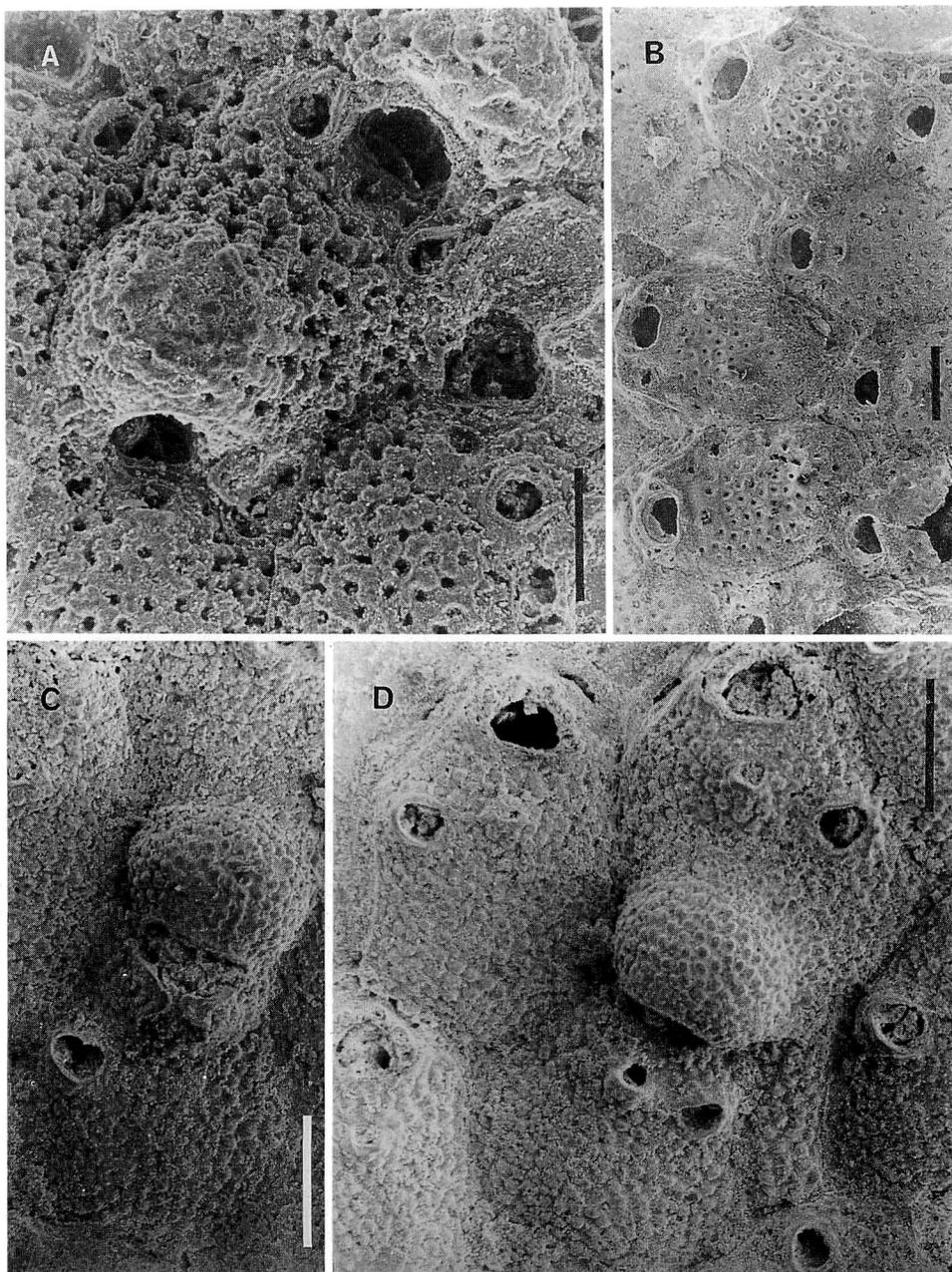


Fig. 8. A, B. *Microporella californica* (Busk). A. Ovicellate zooids. B. Younger zooids. C, D. *Microporella* cf. *gibbosula* Canu and Bassler. C. An ovicellate zooid with a sinuate peristome. D. General morphotype, peristome not developed.

Genus *Calloporina* Neviani, 1895

***Calloporina hayamiae* sp. nov.**

Fig. 9A

Calloporina sculpta: Nishizawa, 1990, p.119, pl. 4, fig. 3. (nec *C. sculpta* Canu et Bassler, 1929)

Specimens. Holotype, CBM-PI-0001425 from Nishiyatsu. Paratype, CBM-PI-0001426 from Nishiyatsu.

Diagnosis. Zoarium encrusting shells. Zoecia hexagonal, flat, separated by a indistinct furrow. Frontal perforated by areolar pores

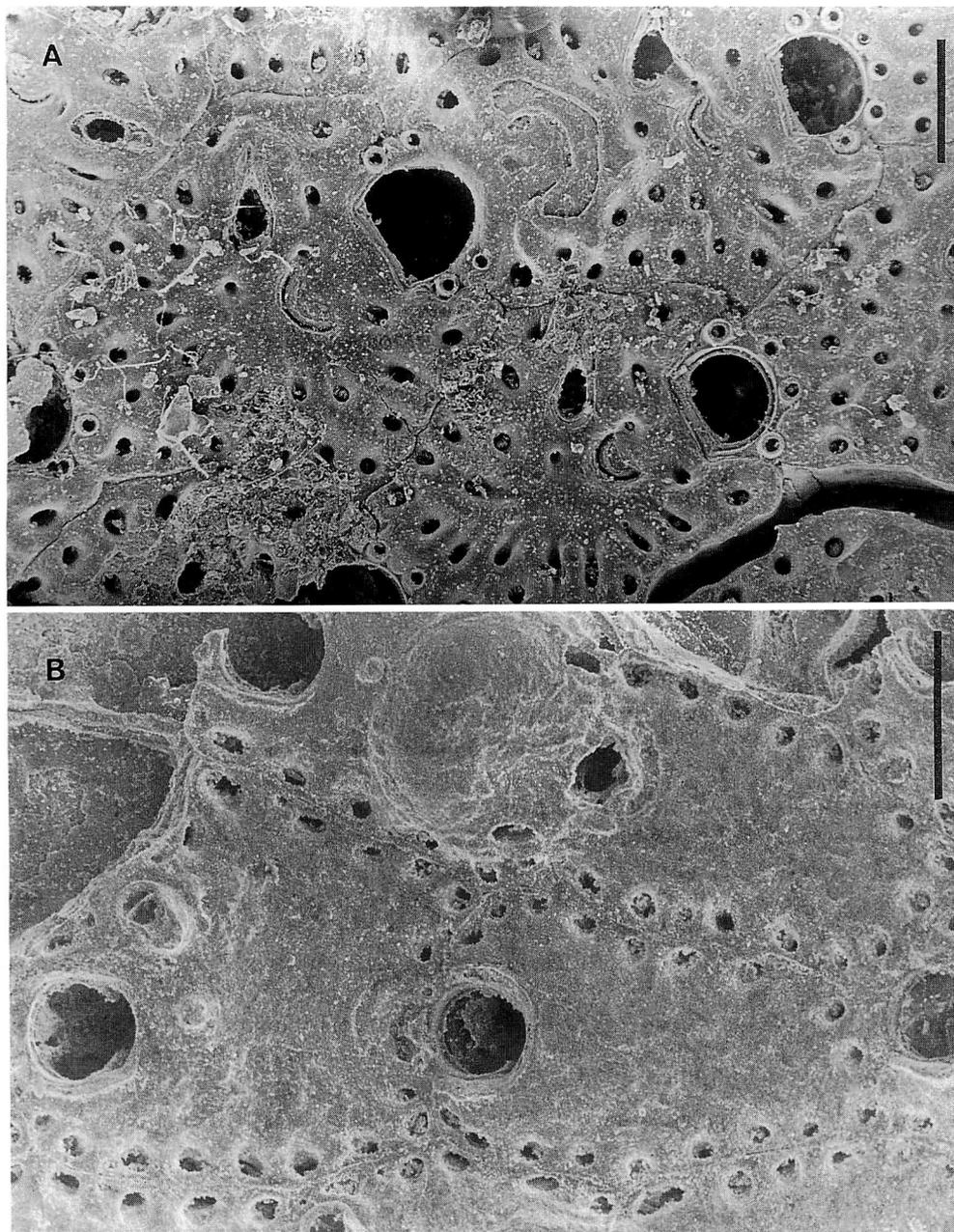


Fig. 9. A. *Calloporina hayamiae* sp. nov. characterized by a narrow crescent ascopore and a very acute avicularian rostrum. B. *Lepraliella biporosa* sp. nov. characterized by two oocelial pores and a pointed or spatulate avicularian rostrum.

and scattered additional pores, some of them with costules. Primary orifice semilunar, with a strait proximal border, often surrounded by a somewhat raised rim; four to six oral spines present, the proximal pair larger generally. Ascopore very narrow, crescentic, situated in

the depression. Avicularia proximo-lateral to the orifice, paired or single, rostrum very acute, directed disto-laterally. Ovicell immersed, with two crescent exposures which are pitted distally and which are forming a concentric circle.

Measurements (in mm).

	Length	Width
Zooecia	0.67–0.76	0.50–0.62
Orifices	0.10–0.16	0.14–0.17
Avicularia	0.14–0.17	0.03–0.07
Ovicells	0.24–0.33	0.33–0.36

Remarks. This species resembles *Calloporina trispinosa* Powell in the features of its ovicell and its frontal wall, but differs in the direction of the avicularia and the absence of a rim surrounding the ascopore.

Nishizawa (1990) recorded *Calloporina sculpta* Canu and Bassler from the early Pleistocene Haizume Formation of Niigata Prefecture. However, its crescent ascopore described by him shows that his specimens are not identical with Canu and Bassler's species. Although all of Nishizawa's specimens (Personal specimen number 99, now kept in Faculty of Science, Chiba University) have no ovicell, his species is conspecific with *C. hayamiae* in all points except for the development of frontal ridges. The frontal ridges of his specimens apparently differ from the "oblique peristome" of *C. sculpta*.

The species name is derived from the late Dr. Tomoko Hayami who did a lot of important research on Japanese Cenozoic bryozoans. *Microporella* sp. II of Hayami (1981) from the Pliocene Ananai Formation on Shikoku Island may be the ill-preserved specimens of this species.

Occurrence. Nishiyatsu.

Family Sertellidae Jullien, 1903

Remarks. Gordon (1984) pointed out that some species in the genus *Cleidochasma* Harmer show features which also occur in the family Sertellidae, especially a beaded orificial rim. He also pointed out that the genus *Hippoporella* Canu, which was assigned to the family Cleidochasmatidae Cheetham and Sandberg by Hayward and Ryland (1979), is regarded as synonymous with the genus *Lepraliella* Levinsen in the family Sertellidae Jullien. On these problems, Soule *et al.* (1991) divided *Cleidochasma* into six genera and stated that some of them need to be assigned to new families.

If the difference of primary orifice is one of most important morphological features for the

familial grouping of Cheilostomata, the Sertellidae may need to be divided, at least into subfamilies, because the primary orifice of the Sertellidae is greatly variable. However, the study on *Cleidochasma* by Soule *et al.* (1991) suggests that the orificial beading is polyphyletic. On the other hand, the Cleidochasmatidae also includes both cleithridiate and lepralioid orifices. Thus I treat the lepralioid cleidochasmatids from the Jizodo Formation as sertellids because not enough is known about the phylogeny of Ascophora except for the difference of the frontal wall.

Genus *Lepraliella* Levinsen, 1917

Lepraliella biporosa sp. nov.

Fig. 9B

Specimens. Holotype, CBM-PI-0001427 from Owada. Paratype, CBM-PI-0001428 from Owada.

Diagnosis. Zoarium encrusting shells, unilaminar. Zooecia quadrate to hexagonal, slightly convex, separated by a thread. Frontal primarily smooth, but occasionally rough by the secondary calcification, areolar pores distinct. Primary orifice horseshoe-shaped, longer than wide, proximal border slightly concave, cardelles pointed, directed to the proximal border, forming two edges of vestibular arch. Avicularia situated proximo-lateral to the orifice, single or paired, rostrum pointed or spatulate, pivot distinct, directed to the median line and somewhat proximally, raised on areolar pores. Three to four pores on the transverse wall and about five pores on each lateral wall. Ovicell prominent, wider than long, with a pair of pores in each proximal corner.

Measurements.

	Length	Width
Zooecia	0.25–0.56	0.13–0.33
Orifices	0.10–0.12	0.10–0.11
Avicularia	0.09–0.10	0.04–0.08
Ovicells	0.22–0.27	0.25–0.30

Remarks. This species resembles *Hippoporella hippopus* (Smitt) especially in the prominent ovicell and the extensive frontal wall (Hayward and Ryland, 1979), but differs in the presence of two pores on the ovicell, the shape

of the avicularia and the regular arrangement of areolar pores. The presence of pores on the ovicell is also observed in the genus *Hippomenella* which is regarded as a hippopodid, but *Hippomenella* has more than two rows of marginal pores and a finely perforated ovicell. The type specimen of *Hippoporella gigantea* Kataoka (IGPS 59274 of the Tohoku University) also has one or two large pores on the ovicell, so I think that *Hippoporella* includes some species with pores on the ovicell.

The genus *Hippoporella* was regarded as synonymous with *Lepraliella* by Gordon (1984). He pointed out that the diagnosis of *Hippoporella* is equally applicable to *Lepraliella* and that both genera may have a smooth or beaded orificial arch. I follow his viewpoint because the orificial beading seems to be polyphyletic (Soule *et al.*, 1991).

The species name is derived from the presence of two pores on the ovicell.

Occurrence. Owada, Nishiyatsu and Kawazai.

Distribution. The Kujukurihama Coast and northward.

Genus *Aimulosia* Jullien, 1888

Remarks. This genus is found in North America, West Africa and Europe (*e.g.*, Winston and Håkansson, 1985). The diagnosis of this genus by Canu and Bassler (1920, 1923), Osburn (1952), *etc.*, is also applicable to *Lepraliella* *sensu* Gordon (1984), but there is a remarkable difference between *Aimulosia* and *Hippoporella* in that the former has a suboral umbo bearing a median avicularium. Considering that a similar difference is regarded as important in two smittinids, *Smittoidea* and *Parasmittina*, *Aimulosia* may be distinguished from *Hippoporella* (*i.e.*, *Lepraliella*). Therefore, I interpret this as a separate genus and place it in the family Sertellidae.

Brown (1952) stated that the proximal lip of the primary orifice in Jullien's specimen of Genotype (*A. australis*) is seen to possess a rather deep, squared sinus. Gordon (1984) thought that *Aimulosia* seemed very close to *Buffonellodes*, because *Buffonellodes* also had such orifices. He concluded that the diagnosis of *Aimulosia* by Osburn (1952) could not refer to Jullien's genus. It is a fact that not enough

comparison with the type-species has been done by Canu and Bassler (1920, 1923), Osburn (1952), Soule (1961), *etc.* However, the conclusion of this problem is reserved in this paper, because I have not yet seen Jullien's specimen.

Aimulosia aculeata Canu et Bassler

Figs. 10A, B

Aimulosia aculeata Canu et Bassler, 1923, pp. 139–140, pl. 21, figs. 10–14.

Specimens. CBM-PI-0001429 from Owada.

Measurements (in mm).

	Length	Width
Zoecia	0.31–0.47	0.26–0.38
Orifices	0.08–0.09	0.09–0.11
Avicularia*	0.09–0.11	0.03–0.04
Ovicells	0.15–0.17	0.21–0.26

* Frontal avicularia

Remarks. The measurements of specimens from the Jizodo Formation are smaller than those of the type specimen. However, Canu and Bassler (1923) stated that their measurements were the largest in this species. The present specimens also resembles *A. brevis* in the rareness of areolar pores, but the latter was established as a species without areolae (Canu and Bassler, 1923, p. 140).

According to Soule and Soule (1964), Hastings remarked that a wide range of variation occurs in her *Hippoporella gorgonensis*, but the type specimen is synonymous with *A. uvulifera* (Osburn). This fact suggests that *H. gorgonensis* reported by Sakakura (1938) may probably include a species of *Aimulosia*.

This is the first record of this genus in Japan. A living colony of *Aimulosia* from Hasaki Harbor of Ibaraki Prefecture (Arakawa, 1992) is this species.

Occurrence. Owada.

Distribution. Hasaki Harbor, Ibaraki Prefecture.

Genus *Cyclocolpota* Canu et Bassler, 1920

Type species. *Cyclocolpota perforata* Canu et Bassler, 1923

Emended Diagnosis. Sertellidae (Cleidochasmatidae) without avicularium. Zoarium en-

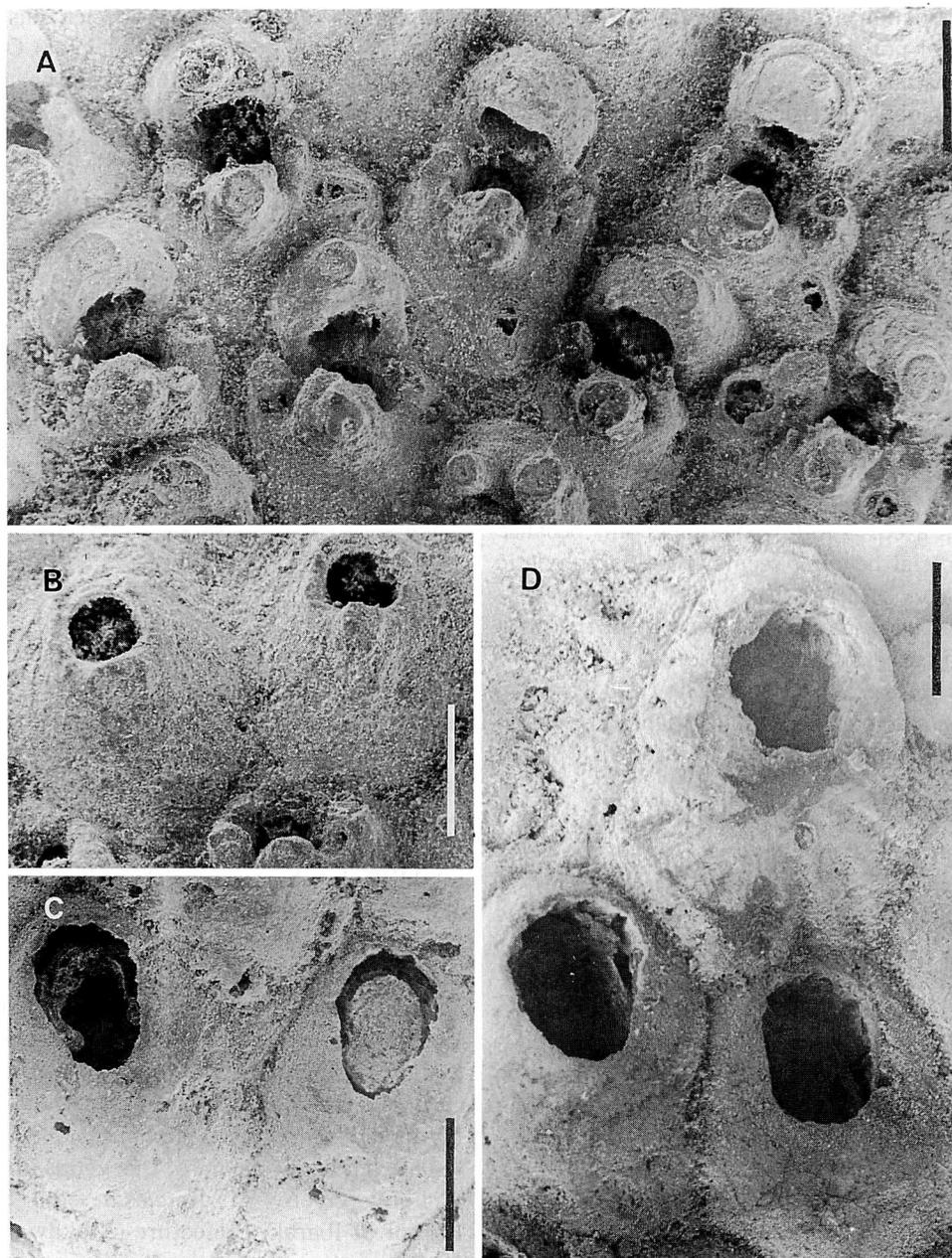


Fig. 10. A, B. *Aimulosia aculeata* Canu and Bassler. A. Ovicellate zooids. B. Zooids of marginal part of colony. C, D. *Cyclocolpota costulata* (Canu and Bassler). C. Vestibular arch and secondary calcification filling the orifice. D. Older zooids.

crusting, multilaminar, consisting of many subcolonies. Primary orifice arched distally, with broad poster, cardelles not so developed. Secondary orifice elliptical. One or two rows of areolar pores present. Basal pore-chambers developed. Ovicell imperforate.

Remarks. Canu and Bassler (1923) stated that this genus has no cardelles. However, the basal view of the type species shows a pair of cardelles (see Canu and Bassler, 1923, pl. 30, fig. 12). In the case of *C. costulata* (Canu and Bassler), described after this discussion, the vestib-

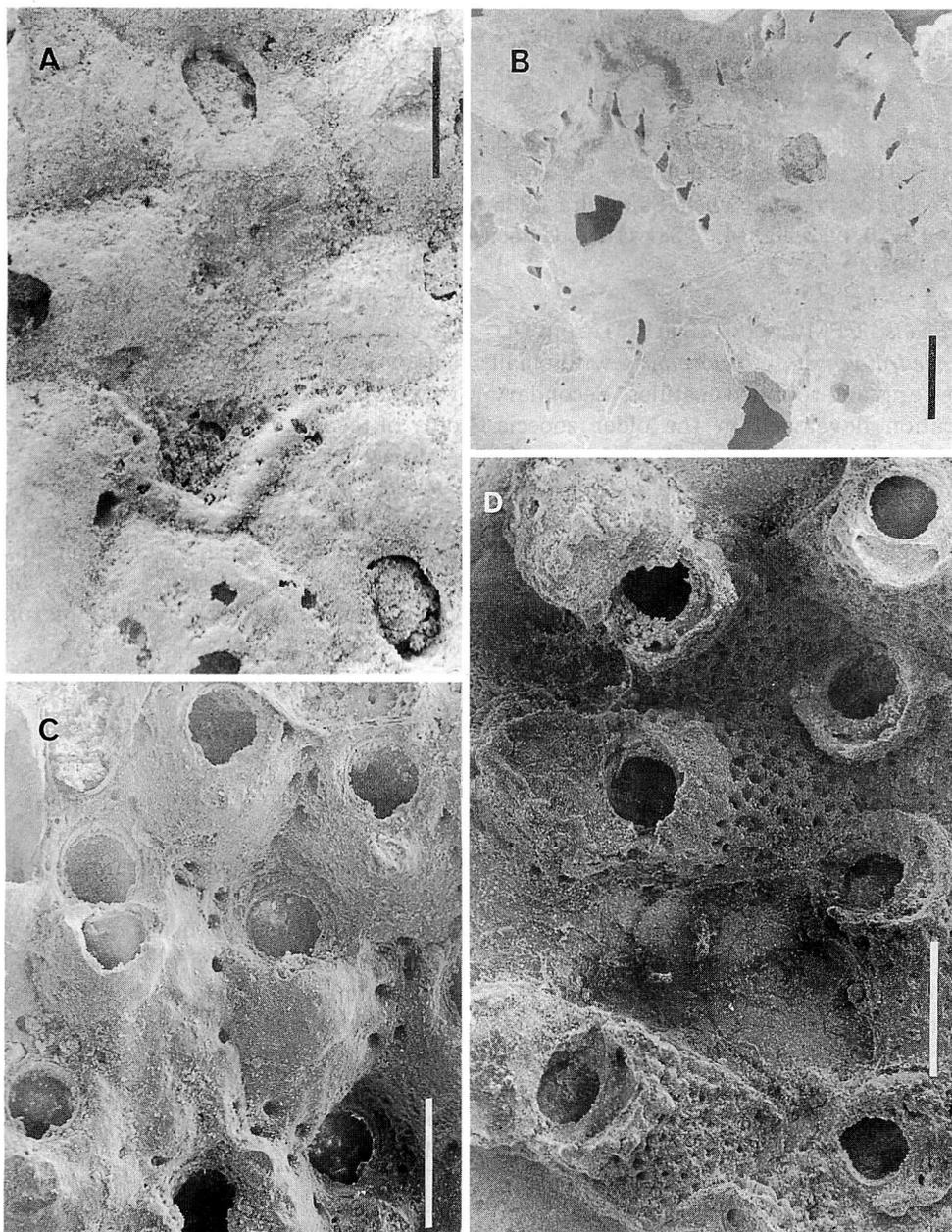


Fig. 11. A, B. *Cyclocolpota costulata* (Canu and Bassler). A. Zone of astogenetic change. B. Basal view of zooids. C. *Rhynchozoon* sp. without frontal avicularia. D. *Phylactella* sp. characterized by a widely sinuated orifice and an ovicell with a flat central area.

ular arch with cardelles is developed in the older zoecia. Although there is no salient cardelles in most specimens, it is clear that their primary orifices with broad poster are also the same type as the genus *Lepraliella* sensu Gordon (1984). But I also interpret this

as a separate genus on the basis of the absence of avicularium.

***Cyclocolpota costulata* (Canu et Bassler),**

comb. nov.

Figs. 10C, D, 11A, B

Schizoporella costulata Canu et Bassler, 1929, pp. 317–318, pl. 36, figs. 10, 11.*Schizoporella costulata distincta* Sakakura, 1935 b, pp. 19–20, pl. 3, figs. 4, 5; Sakakura, 1935c, pp. 111–112.*Specimens.* CBM-PI-0001430, 1431 from Oi.

Emended diagnosis. *Cyclocolpota* with small areolar pores and rounded costules. Secondary calcification developed in the older zooecia. Frontal convex, smooth in the younger zooecia, rough in the older zooecia. A pair of cardelles developed as two edges of vestibular arch in the older zooecia. Secondary orifice elliptical to pyriform, longer than wide. Heterozooids without orifice present. Orifice often filled with the secondary calcification. Five to six pairs of basal pore-chambers present.

Measurements (in mm).

	Length	Width
Zooecia	0.31–0.70	0.25–0.48
Orifices	0.10–0.26	0.07–0.21

Remarks. Canu and Bassler (1929) placed this species in the genus *Schizoporella* Hincks because of the shape of its operculum, but it can not be placed in *Schizoporella* because its frontal wall is not perforated. Canu and Bassler stated that this species could be classified exteriorily in the genus *Cyclocolpota* Canu and Bassler, but they did not find the “characteristic parietal diettelae”. However, the specimens from the Jizodo Formation have five to six pairs of basal pore-chambers (Fig. 11B).

This species resembles *C. perforata* Canu and Bassler in many points except for the frontal granulation and the ovicell. Both species have two rows of areolar pores, although it is generally one row in *C. costulata*. The presence of zooecia without an orifice is also common in these two species. They are distinguished by their difference in the shape of the secondary orifice and the frontal granulation. The ovicell of *C. costulata* has not been found yet, although I observed many specimens. This species seems to have no ovicell.

The secondary calcification filling the orifice is common in this species (Fig. 10C). It resembles the thin “frontal walls” found in the ectoproctolith of *Antropora tincta* (Hastings) by Nishizawa (1985).

The older zooecia occasionally have an orifice with a small anter (about two-thirds the width of a normal zooecia). Sakakura (1935b) regarded them as a subspecies. The variation of the orifice in the same colony suggests a variation of lophophores. It is known that the colony-wide current system reflected in the variation of lophophores has the function not only of feeding but also of the release of spermatozoa (e.g., Cook, 1977).

Occurrence. Owada, Hogisaku, Oi, Nishiyatsu, the Nanamagari Shrine, Atebi, Jizodo, Yamadakubo, Kawazai and the Nagara-dam.

Distribution. Philippine to Japan. This species seems to be the only example of living species in *Cyclocolpota*.

Genus *Rhynchozoon* Hincks, 1895***Rhynchozoon* sp.**

Fig. 11C

Specimens. CBM-PI-0001432 from Nishiyatsu.

Description. Zoarium encrusting shells. Zooecia distinct, oval, quite convex, often elevated distally, separated by deep grooves. Frontal smooth, with small marginal pores. Primary orifice almost rounded, with a shallow sinus, finely crenulated; peristome generally developed, with a few of protuberances. Suboral avicularium directed laterally, often wanting. No frontal avicularium.

Measurements (in mm).

	Length	Width
Zooecia	0.38–0.57	0.19–0.35
Orifices	0.10–0.13	0.10–0.11
Avicularia*	0.19	0.10

* Avicularian chamber

Remarks. This species resembles *Rhynchozoon* sp. of Hayami (1971) in the absence of frontal avicularia, but differs in the convex frontal wall and the frequent absence of suboral avicularia.

Rhynchozoon sp. reported by Arakawa (1992) is also characterized by a frequent absence of

suboral avicularia and a primary orifice very similar to this species. However, I hesitate to regard them as the same species because the living species has scattered but distinct frontal avicularia.

Occurrence. Hogisaku, Oi, Nishiyatsu, Ichinosawa and the Nagaradam.

Family Teuchoporidae Neviani, 1895

Remarks. The family Phylactellidae Canu

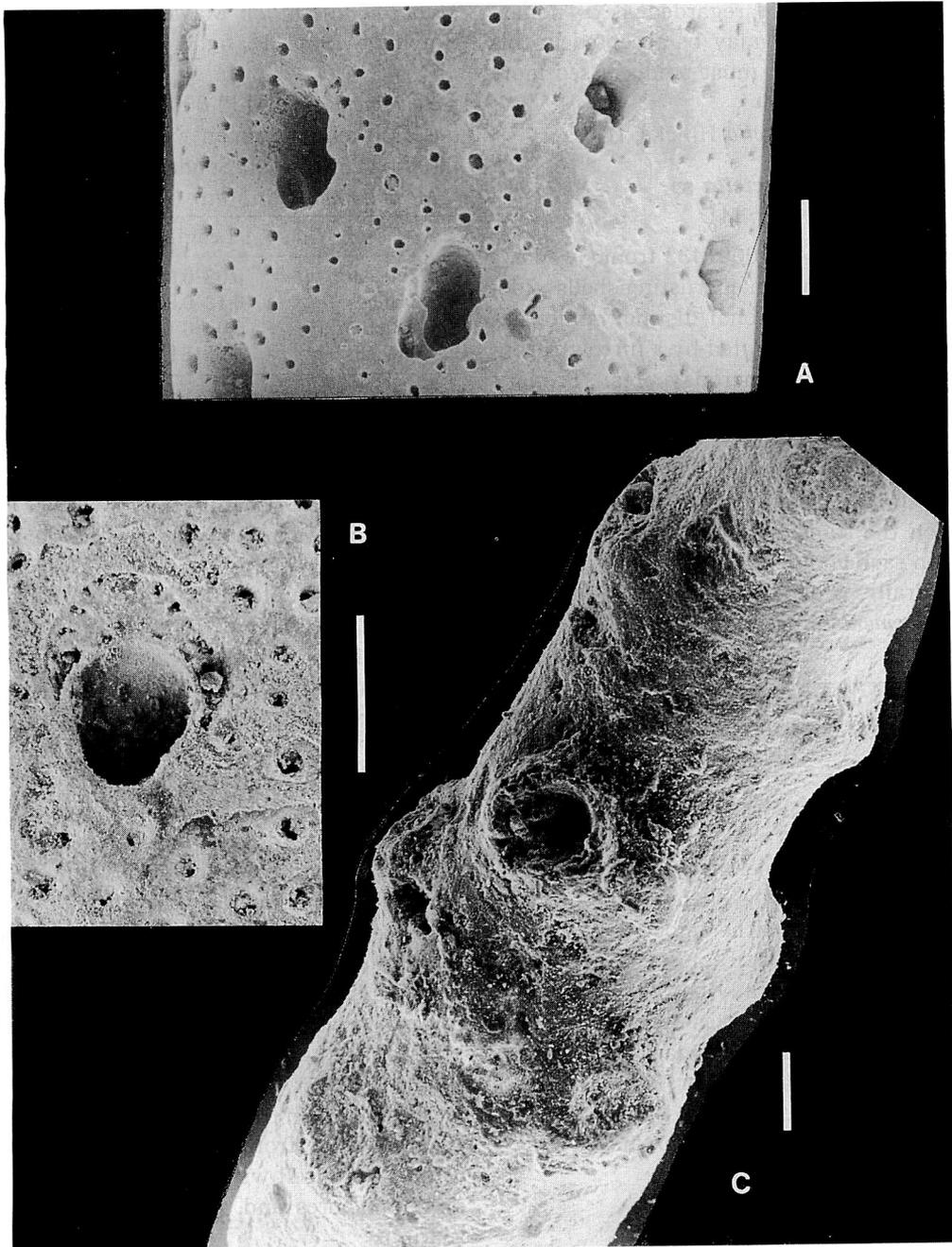


Fig. 12. A, B. *Myriozoum serratum* Mawatari. A. Cylindrical colony and zooids with suboral avicularia. B. Ovicell with a crescent area bearing minute marginal pores. C. Cylindrical colony of *Haswellina* (?) sp. with a tubular peristome.

and Bassler has been accepted as a valid name even after Harmer (1957) indicated the priority of the name Teuchoporidae Neviani (e.g., Hayward and Ryland, 1979). Gordon (1984) seems to have followed Harmer's indication, although he did not discuss in detail. Inasmuch as the Teuchoporidae is not regarded as a "nomen oblitum", its priority may be accepted in this study. This problem must be discussed more adequately.

Genus *Phylactella* Hincks, 1879

***Phylactella* sp.**

Fig. 11D

Specimens. CBM-PI-0001433 from Owada.

Description. Zoarium encrusting shells. Zooecia elliptical to hexagonal, distinct, somewhat elevated distally, separated by a furrow. Frontal perforated by numerous pores. Primary orifice elliptical, wider than long, with broad and shallow sinus. Peristome flared, with a crescent depression between its proximal part and the orifice. No avicularium. Four large pores on the transverse wall and ten or more pores on each lateral wall. Ovicell imperforate, flat centrally, wider than long.

Measurements (in mm).

	Length	Width
Zooecia	0.33–0.40	0.20–0.40
Orifices	0.08–0.10	0.08–0.11
Ovicells	0.16–0.18	0.23–0.25

Remarks. This is the first record of *Phylactella* in Japan.

This species resembles *P. infundibulum* Canu and Bassler, 1917 in the shape of the primary orifice, but differs in the imperforate ovicell and the absence of distal tongue of peristome. The phylactellid generally has a perforate ovicell. However, some species seem to form imperforate ovicells with secondary calcification, such as *Phylactellipora eximia* (Hincks) in Hayward and Ryland (1979).

Occurrence. Owada and Nishiyatsu.

Family Myrionozoidae Smitt, 1867

Genus *Myrionozoum* Donati, 1750

***Myrionozoum serratum* Mawatari**

Figs. 12A, B

Myrionozoum serratum Mawatari, 1952b, p. 249, text-fig. 19, pl. 12, fig. 8.

Specimens. CBM-PI-0001434 from Nishiyatsu. Holocene specimen with an ovicell, CBM-PI-0001435 from off Sendai was added.

Measurements (in mm).

	Length	Width
Zooecia	0.68–0.88	0.33–0.44
Orifices	0.13–0.22	0.10–0.15
Avicularia*	0.08–0.14	0.04–0.05
Ovicells	0.15	0.23

* Avicularian chamber

Remarks. Mawatari (1952b) compared this species with *Myrionozoum pulchrum* Ortmann and *M. superficiale* Ortmann. This species is different from *M. pulchrum* in the shape of its primary orifice and oral avicularium. The shape of the orifice resembles *M. superficiale*, but an avicularium is absent in Ortmann's species.

The ovicell of this species was not described in Mawatari's paper. I collected ovicellate zooids from off Sendai during the GH81-2 Cruise of the Hakurei-maru (Fig. 12B). This species has an ovicell with a crescent area bearing minute marginal pores. It shows that this species belong to a different genus from *M. subgracile* d'Orbigny. However, I cannot determine its taxonomic position yet.

The features of the ovicells closely resemble the genus *Celleporina* Gray, but the frontal perforation is distinctive in this species. *Celleporina notoensis* Hayami also has a *Celleporina*-type ovicell and a perforated frontal wall (Hayami, 1975). *C. notoensis* and *M. serratum* may be placed in the same family characterized by a distinct frontal perforation, a sinuate orifice, an ovicell with a crescent area bearing marginal pores and, perhaps, an arborescent zoarium.

Occurrence. Oi, Nishiyatsu, Ichinosawa, the Nanamagari Shrine, Atebi, Jizodo, Kawazai and the Nagara-dam.

Distribution. Off Wakayama and Off Minabe, Wakayama Prefecture (Mawatari, 1952b); off the east coast of Boso Peninsula, Chiba Prefecture (Arakawa, 1984); off Sendai, Miyagi Prefecture. The fragments of this species are abundant in the coarse-grained sands of Pacific shelf in Japan.

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房総半島の更新統地蔵堂層中のコケ虫フォーナ

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地蔵堂層産コケ虫化石について、群体の破片数を用いた R モードの手法で 5 つの種群 (アソシエーション) に分類し、その層相と対応した分布を研究した。

いわゆる "sand fauna" の種を含んでいる *Cellaria punctata*-*Thalamoporella novaehollandiae* Association と、硬質起立性群体の種を多く含む *Myriozoum serratum*-*Microporella californica* Association は、いずれも陸棚砂底の層相に豊富である。被覆性種の貝殻上での活発な群体形成で特徴づけられる *Verminaria areolae*-*Hippoporina purpurata* Association は、非三角州性沿岸域の層相に多産する。関東地方の沿岸域に棲息する種を多く含んでいる *Celleporella hyalina*-*Watersipora aterrima* Association は、沖合相である「地蔵堂化石帯」以外の全ての層相に普通に産する。*Aimulosia aculeata* Association は、湾口砂相と考えられるヒメアサリ貝層に特徴的である。

尚、*Hippoporina*, *Calloporina*, *Lepraliella* の新種 3 種を含む、23 種の唇口類を記載した。