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The fossil on the cover is *Trilophodon sendaicus* Matsumoto, an extinct elephant, which was described from the Pliocene Tatsunokuchi Formation developed in the vicinity of Sendai, Northeast Honshu, Japan. (IGPS coll. cat no. 87759 (A), length about 18.5 cm)

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940. FOSSIL NONARTICULATED CORALLINE ALGAE AS DEPTH INDICATORS FOR THE RYUKYU GROUP*

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Abstract. Fossils of nonarticulated coralline algae occur in the coral limestone of the Pleistocene Ryukyu Group distributed in Yoron, Okierabu, Toku and Kikai Islands. Four fossil nonarticulated coralline algal assemblages are compared with their Recent coralline algal depth distribution in the Ryukyu Islands. Each assemblage represents a particular depth range. Depositional environments inferred from the Pleistocene coralline assemblages accord well with those based on hermatypic corals and benthic foraminifera.

Key words. Nonarticulated coralline algae, depth indicator, species assemblage, Pleistocene, Ryukyu Group.

Introduction

Nonarticulated coralline algae (Coralinaceae, Rhodophyta) play an important framework-building role, together with hermatypic corals, in Tertiary to Recent reef formations. For example, they may cover more than 30% of the reef surface in some modern reefs (Littler, 1973a, 1973b; Iryu and Matsuda, 1988). Intensive ecologic studies on the nonarticulated corallines in the modern tropical reef environment have been conducted since the 1960's. This enables us to make use of these organisms for paleoenvironmental interpretation. Studencki (1979) and Bosence and Pedley (1982) analyzed depositional environments of algal-related biofacies mainly based on the coralline morphology, while Mankiewicz (1988) and Jones and Hunter (1991) used the coralline assemblages as a depth indicator.

The Pleistocene Ryukyu Group, reef complex deposits, consists of limestones and related terrigenous sediments. The fossil

corallines occur abundantly as crusts in the coral limestone or as an aggregated form of foraminiferal-algal nodules (rhodoliths) forming a distinct lithofacies called the rhodolith limestone. Heydrich (1900) first studied these fossil corallines in the Ryukyu Group and described *Lithothamniscum na-haense*, an important constituent of the flora. However, taxonomic works were undertaken later by Ishijima (1938, 1942a, 1942b, 1944, 1954), who described 16 nonarticulated and 27 articulated coralline algal species. Minoura (1979a, 1979b) and Minoura and Nakamori (1982) investigated a sedimentological aspect of the rhodolith limestone and Iryu (1984, 1985) revised these results based on a study of Recent rhodoliths. Since paleoenvironmental significance of the fossil corallines in the coral limestone has not been examined, however, they have not widely been used as paleoenvironmental indicators. In contrast, Noda (1976) and Nakamori (1986) used benthic foraminifers and hermatypic corals as paleoenvironmental indicators, and mapped the distribution of biota and various sediment types in the reef-

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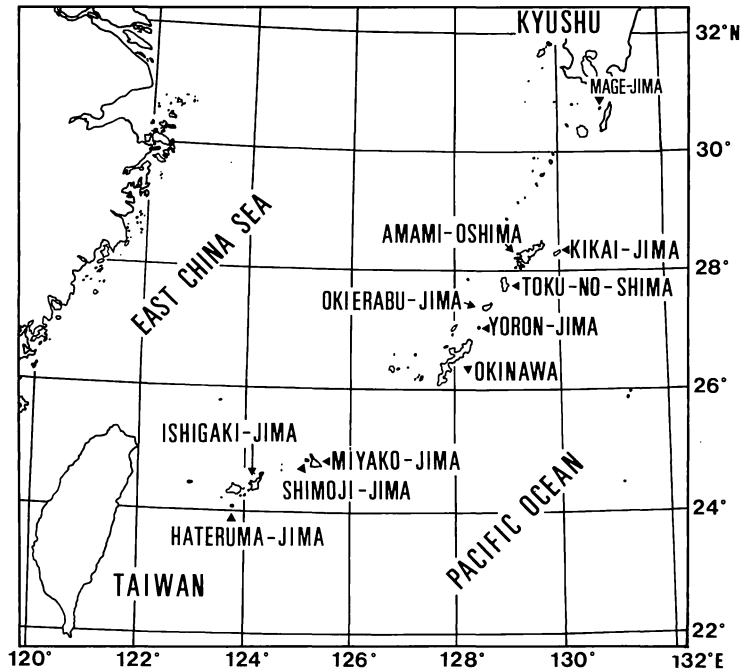


Figure 1. Map showing locations of the study area.

complex facies at the time of deposition of the Ryukyu Group.

This paper aims at establishing the usefulness of fossil nonarticulated coralline algae in a coral limestone facies as depth indicators for the Ryukyu Group; that is to establish a "coralline bathymeter," in the following manner. The distribution of living corallines in the reefs around the Ryukyu Islands is reviewed. These data, coupled with those from Guam (Gordon *et al.*, 1976) and Hawaii (Adey *et al.*, 1982), form a basis to select depth-indicative species from the fossil corallines occurring in the Ryukyu Group. This in turn enables to circumscribe discrete species assemblages, each of which represents a particular depth range. Paleobathymetric accuracy based on the coralline assemblages will then be tested against those derived from the coral communities (Nakamori, 1986) and benthic foraminiferal assemblages (Noda, 1976).

The taxonomy used for identifying corallines coming under the subfamilies Litho-

phylloideae and Melobesioideae is that of Woelkerling (1988), with some later nomenclatural modification, such as disposition of *Titanoderma* proposed by Campbell and Woelkerling (1990). However, the extended generic concept of *Spongites* (subfamily Mastophoroideae), which encompasses the genera *Porolithon*, *Hydrolithon*, and *Pseudolithophyllum sensu Adey (1970)* as heterotypic synonyms of *Spongites* (Penrose and Woelkerling, 1988), is not adopted and the latter three genera are conserved.

Living nonarticulated coralline algae

The reef complexes around the Ryukyu Islands are divided into three basic topographic zones; reef flat, reef slope, and island shelf. Nonarticulated coralline algae are distributed in all three zones (Figure 2).

Reef Flat

No quantitative investigation on the coralline algae inhabiting the reef flat has been conducted. The following evidence is avail-

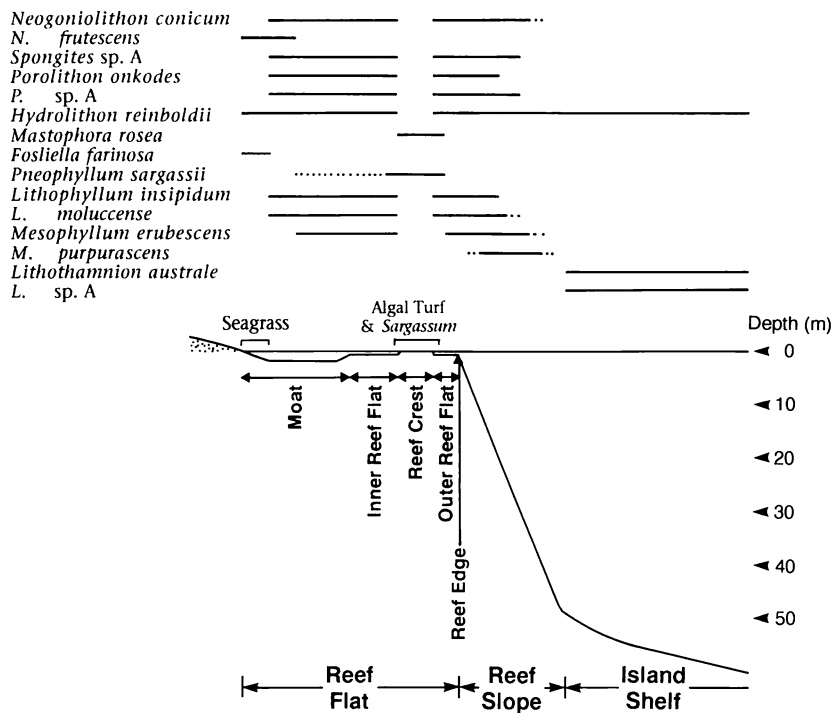


Figure 2. Schematic diagram showing distribution of nonarticulated coralline algae in reefs around the present-day Ryukyu Islands

able on the distribution of coralline algae at a qualitative level.

(1) Eighteen species coming under nine genera of the nonarticulated coralline algae are identified (Iryu, 1991a, 1991b). They are *Neogoniolithon conicum* (Dawson) Gordon, Masaki et Akioka, *N. fosliei* sensu Matsuda (1989), *N. frutescens* (Foslie) Setchell et Mason, *Spongites* sp. A (= *Spongites* sp. A in Iryu and Matsuda (1988)), *Porolithon onkodes* (Heydrich) Foslie, *Porolithon* sp. A (= *Porolithon* sp. A in Iryu and Matsuda (1988)), *Hydrolithon reinboldii* (Weber van Bosse and Foslie) Foslie, *Mastophora pacifica* (Heydrich) Foslie, *M. rosea* (C. Agardh) Setchell, *Fosliella farinosa* (Lamx.) Howe, *Pneophyllum sargassii* (Foslie) Chamberlain, *Lithophyllum insipidum* Adey, Townsend et Boykins, *L. kotschyianum* Unger, *L. moluccense* (Foslie) Foslie, *L. pallescens* (Foslie) Foslie (= *L. okamurai* Foslie), *Mesophyllum erubescens* (Foslie) Lemoine, *M. mosemor-*

phum (Foslie) Adey, and *M. syrphetodes*? Adey, Townsend et Boykins.

(2) Some species show a wide range in their distribution and others are found in a particular habitat. *Neogoniolithon conicum*, *Spongites* sp. A, *Porolithon onkodes*, *Porolithon* sp. A, *Hydrolithon reinboldii*, *L. insipidum*, and *L. moluccense* grow abundantly on well-illuminated rocky substrata and rubble in most of the reef flat except for near-shore seagrass bed (Iryu and Matsuda, 1987). The habitats of *N. frutescens*, *M. rosea* and *L. pallescens* are very limited: *N. frutescens* is found in the shore-side-half of the moat, covering gravels which originated from calcified skeletons, to form open to densely branched algal nodules; *L. pallescens* is seen in places through which strong currents flow such as the strait of the Kabira Cove (Matsuda, 1987); *M. rosea* occurs in and around the *Sargassum* thicket flourishing on the seaward margin of the reef crest.

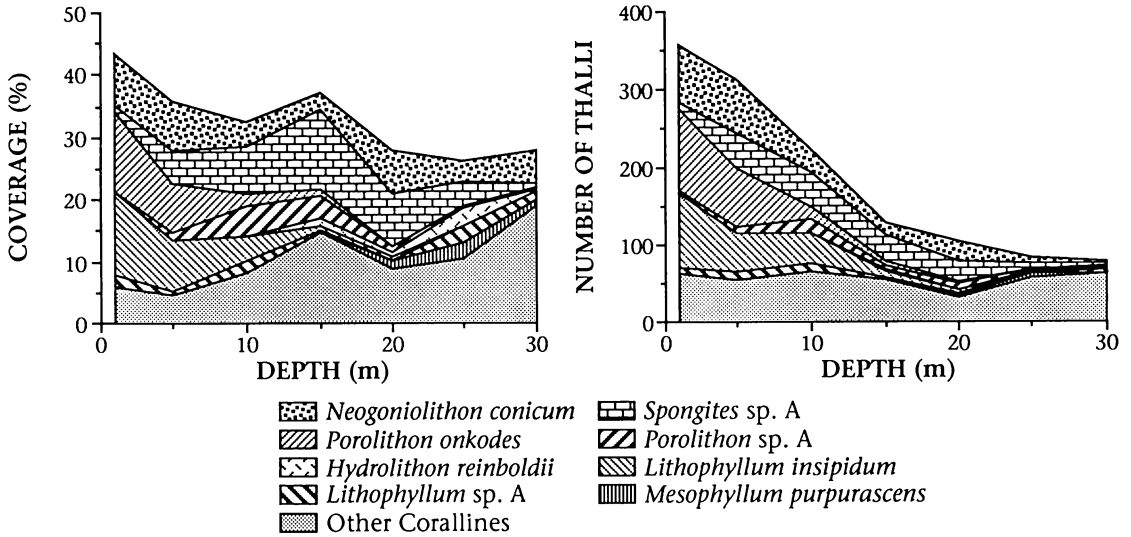


Figure 3. Coverage and density (number of thalli/c.a. 3,200 m²) distribution of nonarticulated coralline algae. Data from Iryu and Matsuda (1988).

Reef Slope

Eighteen species coming under seven genera are recognized. They are *Neogoniolithon colli* (= *Rhizolamellia colli* Sheveiko), *N. conicum*, *N. fosliei*, *N. fosliei sensu* Matsuda (1989), *Spongites* sp. A, *Porolithon onkodes*, *Porolithon* sp. A, *Hydrolithon laeve*? (= *Hydrolithon* sp. in Iryu and Matsuda (1988)), *H. reinboldii*, *Hydrolithon* sp. A, *Mastophora pacifica*, *Lithophyllum insipidum*, *L. kotschyannum*, *L. moluccense*, *Lithophyllum* sp. A (= *Lithophyllum* sp. A in Iryu and Matsuda (1988)), *Mesophyllum erubescens*, *M. purpurascens*, and *M. syrphetodes*?

Iryu and Matsuda (1988) measured the standing crop of the nonarticulated coralline algae on well-illuminated flat rocky substrata in the forereef environment down to 30 m depth and their results are summarized as follows (Figure 3). The mean total coverage and density are 33.0% and 5.6 thalli/100 cm², respectively, throughout the investigated depth range. The dominant species are *N. conicum*, *Spongites* sp. A, *P. onkodes* and *L. insipidum*. *Neogoniolithon conicum* is distributed throughout the observed depth

range, not showing a regular pattern in its standing crop distribution, and its mean density ranks first of all the species. *Spongites* sp. A has the greatest mean coverage and its standing crop is highest at 15 m depth. *Porolithon onkodes* and *L. insipidum* are most abundant at 1 m depth, but they decrease markedly with increasing depth and are entirely absent below 20 m.

Based on such a depth distribution, three nonarticulated coralline algal assemblages are discriminated; Assemblage I, II and III. Assemblage I is distinguished by abundant *P. onkodes* and *L. insipidum* and its depth ranges 0–15 m. Assemblage II is characterized by the common to abundant occurrence of *Spongites* sp. A. Depth range of Assemblage II is between 15 and 25 m, where *P. onkodes* and *L. insipidum* are scarce down to 20 m and are entirely absent below that. Assemblage III, observed deeper than 25 m, is delineated by the common growth of *N. conicum*. *Spongites* sp. A is seldom found, whereas *M. purpurascens* with extensive thalli is sporadically distributed in this depth range.

The coralline-algal flora has not been inves-

tigated at depths from 30 to 50 m.

Island Shelf

Extensive investigations of biota and sediments by such authors as Nohara *et al.* (1979), Iryu (1984, 1985), Iryu and Hayasaka (1985), Matsuda and Tomiyama (1988), and Tsuji *et al.* (1989) have revealed that the rhodoliths, nodules composed predominantly of nonarticulated coralline algae, are distributed commonly on the deep foreereef to island shelf in waters from 50 to 200 m deep around the Ryukyu Islands. Recently, Matsuda *et al.* (1992) showed the distribution, abundance, and composition of rhodoliths based on 119 grab samples taken around Okinawa-jima at depths from 50 to 200 m. The rhodoliths are found from 70 sites in depths from 50 m to 135 m. The mean coverage of the rhodoliths is about 45 % in that area. These rhodoliths are spheroidal, ellipsoidal, or rarely a disclike shape, 5–10 cm (up to 15 cm) in mean diameter, and consist mainly of thin crustose forms of nonarticulated coralline algae and the encrusting foraminifer *Gypsina plana* (Carter), both of which are closely superposed to form a more or less concentric or irregular internal structure. Twenty-eight species of the nonarticulated coralline algae have been identified,

coming under the genera *Spongites*, *Hydrolithon*, *Lithoporella*, *Lithophyllum*, *Mesophyllum*, and *Lithothamnion*. Of these, *Lithothamnion* is the most dominant and diverse, comprising 11 species. The nonarticulated coralline algae grow commonly, covering 40 to 50% of the surface of the rhodoliths at depths less than 120 m, whereas *G. plana* predominates in depths exceeding 120 m.

Fossil nonarticulated coralline algae

Field Setting

Fossil nonarticulated coralline algae were studied from the Yoron-jima, Shimohirakawa and Kamishiro, Sakibaru, and Takigawa Formations on Yoron-jima, Okierabu-jima, Toku-no-shima, and Kikai-jima, respectively. There were 14 localities in Yoron-jima, 11 in Okierabu-jima, 10 in Toku-no-shima and 9 in Kikai-jima (Figures 4, 5, 6 and 7). Okierabu-jima and Kikai-jima were selected for

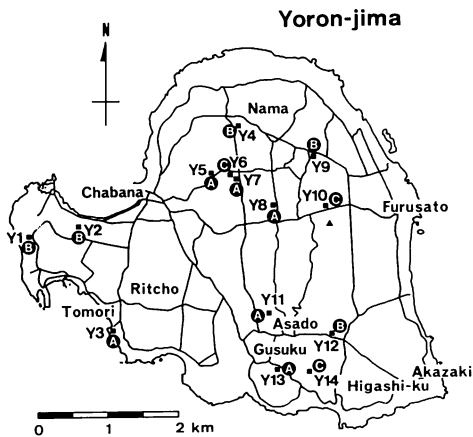


Figure 4. Map showing localities of sampling sites and their coralline-algal assemblages (white letter in solid circle) in Yoron-jima. Lines drawn in the map are roads.

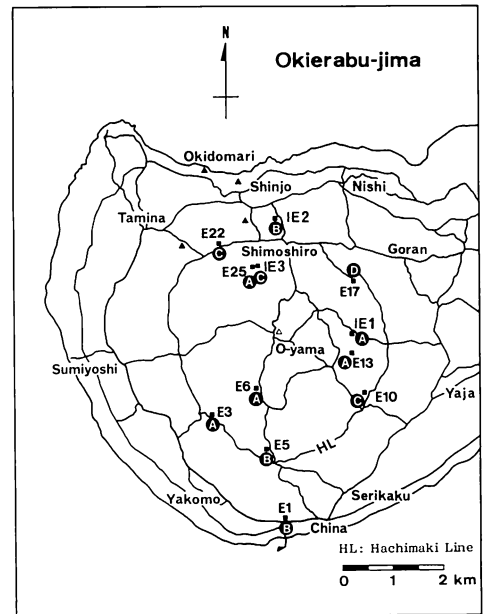


Figure 5. Map showing localities of sampling sites and their coralline-algal assemblages (white letter in solid circle) in Okierabu-jima. Lines drawn in the map are roads.

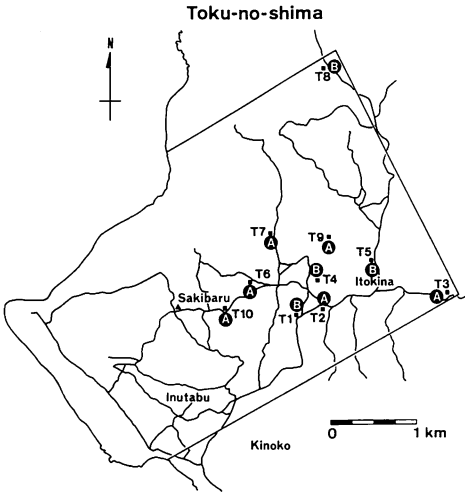


Figure 6. Map showing localities of sampling sites and their coralline-algal assemblages (white letter in solid circle) in Toku-no-shima. Lines drawn in the map are roads.

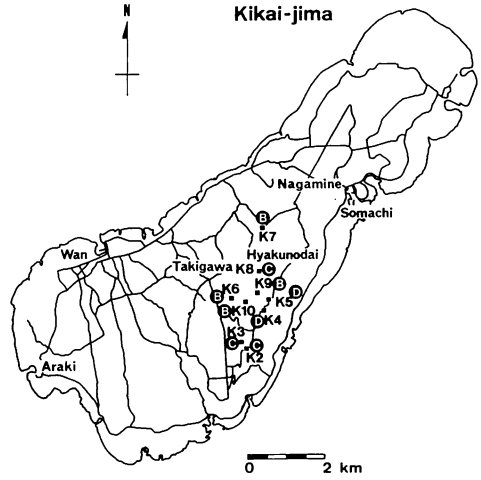


Figure 7. Map showing localities of sampling sites and their coralline-algal assemblages (white letter in solid circle) in Kikai-jima. Lines drawn in the map are roads.

Table 1. List of fossil nonarticulated coralline algae. Unit of occurrence in the table refers to the percentage of thin sections in which each species was present to the total number of sections examined.

Species	Yoron-jima														Okierabu-jima										Toku-no-shima										Kikai-jima																								
	Yoronjima F.														S. F.										Kamishiro E.										Sakibaru F.										Takigawa F.														
Locality	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10										
<i>Neogoniolithon fosliei</i>	○	○	○												○	●														○	○	○	○	○	○	○	○	○	○																				
<i>N. fosliei sensu Matsuda (1989)</i>																																																											
<i>Spongités</i> sp. A																																																											
<i>Porolithon onkodes</i>																																																											
<i>P.</i> sp. A																																																											
<i>Hydrolithon improcerum</i>																																																											
<i>H. reinboldii</i>																																																											
<i>H.</i> sp. A																																																											
<i>Pseudolithophyllum</i> spp.																																																											
<i>Lithoporella melobesioides</i>																																																											
<i>Mastophora pacifica</i>																																																											
<i>Lithophyllum insipidum</i>																																																											
<i>L. tesellatum</i>																																																											
<i>L.</i> sp. B																																																											
<i>L.</i> spp. (branched form)																																																											
<i>Mesophyllum crubescens</i>																																																											
<i>M. purpurascens</i>																																																											
<i>Lithothamnion australe</i>																																																											
<i>L. funafutiense</i>																																																											
<i>L.</i> sp. A																																																											
<i>Archaeolithothamnium erythraeum</i>																																																											
Number of sections examined	21	14	14	11	10	12	14	14	12	13	30	15	21	21	24	35														17	16	30	17	16	21	24	23	21	26	30	25	18	23	20	22	26	22	21											
Assemblage	B	B	A	B	A	C	A	A	B	C	A	B	A	C	B	B														B	A	A	B	B	A	A	B	A	A	C	C	D	D	B	B	C	B	B											

○-20%; ○-40%; ▲-60%; ■-80%; ●-100%

comparison of paleoenvironments inferred from fossil corallines with those based on fossil corals by Nakamori (1986), and some specimens were collected from the same outcrops where he examined fossil corals. Yoron-jima was also investigated for comparison with benthic foraminifers by Noda (1976). Toku-no-shima was chosen because

fossil corallines occur in the best state of preservation among the Ryukyu Islands. The stratigraphy of these islands has been discussed by previous works (Yoron-jima, Noda (1976), Iryu (1986); Okierabu-jima, Iryu *et al.* (1992); Toku-no-shima, Iryu and Yamada (1991); and Kikai-jima, Nakamori (1986)).

Floristic Characteristics

Some 955 thin sections were examined in this study. Eighteen species coming under 11 genera of fossil nonarticulated coralline algae whose thalli appear to be *in situ* were counted and listed (Table 1). This list does not include the corallines which seem to have grown in a cryptic, shaded environment as judged from their growth directions; such cryptic flora is beyond the scope of my investigation of the modern coralline-algal distribution and thus is of no use for establishing a "coralline bathymeter". Fragments of 2 branched (*N. frutescens* and *L. moluccense*) and 1 leafy (*N. colli*) species are also recognized, although not counted and listed. Among those species known from the Ryukyu Group, the following species have been reported from reefs in the present-day Indo-Pacific region: *Neogoniolithon colli*, *N. fosliei*, *Porolithon onkodes*, *Hydrolithon reinboldii*, *Lithoporella melobesioides* (Foslie) Foslie, *Mastophora pacifica*, *Lithophyllum insipidum*, *L.*

moluccense, *L. tesellatum* Lemoine, *Mesophyllum erubescens*, *M. purpurascens*, *Lithothamnion australe* Foslie, *L. funafutiense* (Foslie) Foslie, and *Archaeolithothamnium erythraeum* (Rothpletz) Foslie. It can be concluded that the coralline-algal floral composition of the Ryukyu Group is almost the same as that of modern Indo-Pacific reef regions. There are some differences in the coralline-algal species composition between Recent and Pleistocene floras in the Ryukyu Islands. *Neogoniolithon conicum*, for example, is very abundant in the present-day Ryukyu Islands, whereas it is not found from the Pleistocene Ryukyu Group. On the other hand, *N. fosliei*, which has a very low level of standing crop in the modern reefs, is rather common in the Pleistocene.

Hydrolithon sp. A and *Lithophyllum* sp. B are new to science and will be described elsewhere. *Hydrolithon improcerum* (Foslie) Foslie has been reported only from the Atlantic Ocean, and this is the first discovery of

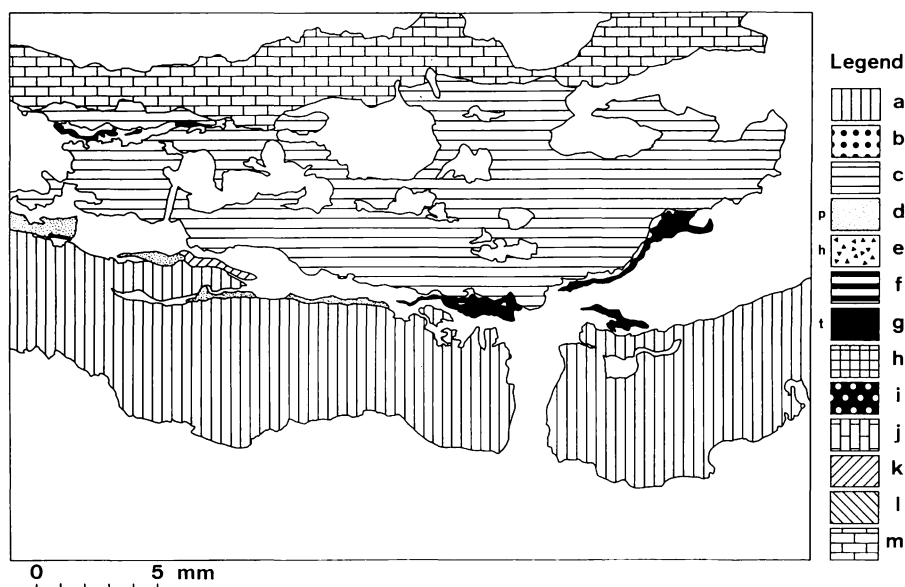


Figure 8. Sketch of a typical example of Assemblage A in E6 (Okierabu-jima). a: *Neogoniolithon fosliei*; b: *Spongites* sp. A; c: *Porolithon onkodes*; d: *Porolithon* ? sp.; e: *Hydrolithon* sp. A; f: *Pseudolithophyllum* sp.; g: *Lithophyllum tesellatum*; h: *Lithophyllum* spp. (branched form); i: *Mesophyllum erubescens*; j: *Lithothamnion funafutiense*; k and l: other nonarticulated coralline algal species; m: corals.

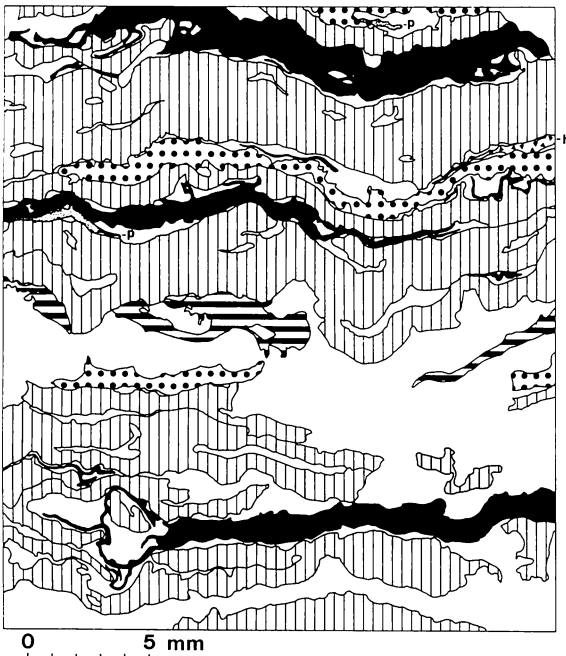


Figure 9. Sketch of a typical example of Assemblage B in IE2 (Okierabu-jima). Legend in Figure 8.

it from the Pacific region. The use of thin sections for coralline identification rendered it impossible to distinguish some branched forms of *Lithophyllum* such as *L. kotschyianum* and *L. pallescens* and they are indicated as "*Lithophyllum* spp. (branched form)" in the list.

Fossil Assemblages

Porolithon onkodes, *Neogoniolithon fosliei*, *Spongites* sp. A, and *Lithothamnion australe* are chosen as depth-indicative species, because they occur from the Ryukyu Group commonly to abundantly and their distribution is very limited in the modern reef environment not only in the Ryukyu Islands but also in Guam (Gordon *et al.*, 1976) and Hawaii (Adey *et al.*, 1982). Based on the presence or absence of these species, four fossil coralline species assemblages are delineated (Assemblages A, B, C and D) and their depth ranges are given as follows.

Assemblage A is characterized by the presence of *P. onkodes* (Figure 8). This species is widely distributed in shallow waters of the tropical Pacific Ocean (Adey *et al.*, 1982;

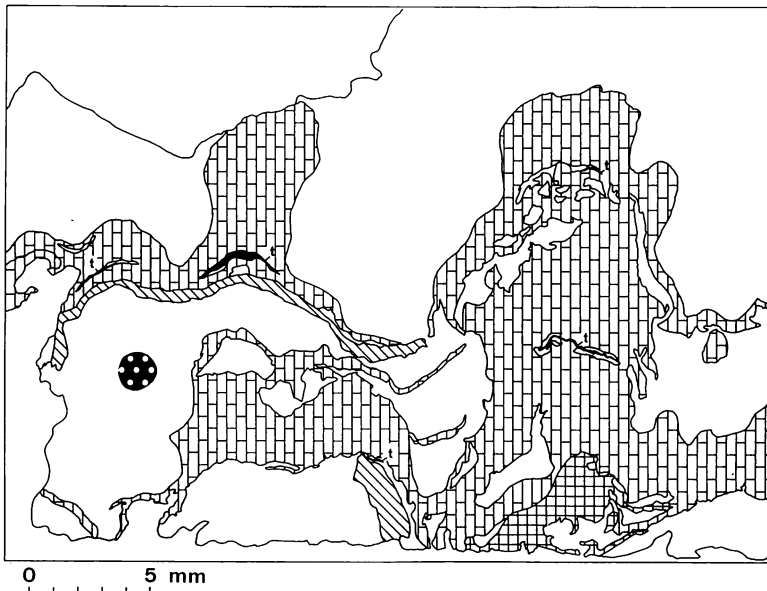
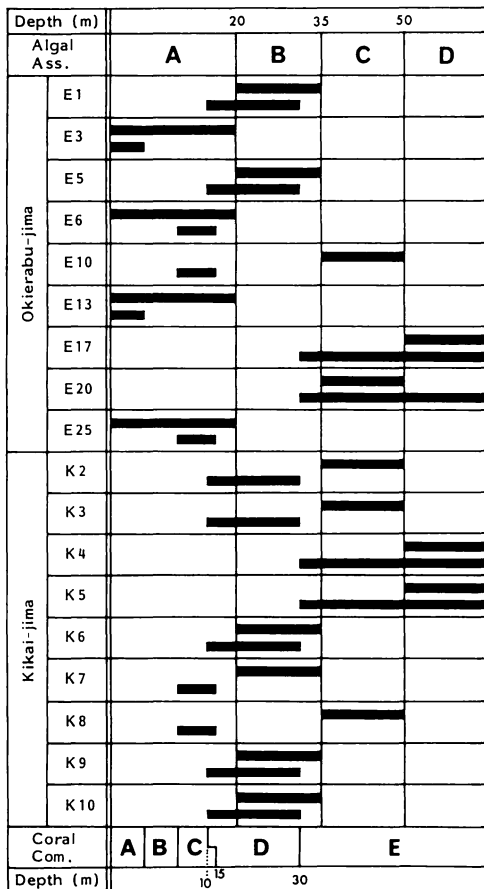


Figure 10. Sketch of a typical example of Assemblage C in E25 (Okierabu-jima). Legend in Figure 8.

Table 2. Delineation of the nonarticulated coralline algal species assemblages and their depth ranges.

Species	Depth Range (m)			
	0-20	20-35	35-50+	50+
Assemblage	Ass. A	Ass. B	Ass. C	Ass. D
<i>Neogoniolithon fosliei</i>	●	●		
<i>N. fosliei sensu Matsuda (1989)</i>	●	●		
<i>Spongites</i> sp. A	●	●		
<i>Porolithon onkodes</i>	●			
<i>P.</i> sp. A	●			
<i>Lithophyllum insipidum</i>	●	●	●	●
<i>L. tesellatum</i>	●	●	●	●
<i>L.</i> spp. (branched form)	●	●	●	●
<i>Lithothamnion australe</i>			●	●
<i>L. funafutiense</i>	●	●	●	●
<i>L.</i> sp. A				●
Rhodolith				●

Table 3. Comparison of depth indicated by the nonarticulated coralline algal species assemblages with that by coral communities by Nakamori (1986). The upper and lower bars in each column show the depth ranges determined by the nonarticulated corallines and by the corals, respectively.



Foslie, 1929; Gordon *et al.*, 1976; Iryu and Matsuda, 1987, 1988; Lee, 1967; Lemoine, 1911; *etc.*). Most of its occurrence is restricted to depths shallower than 20 m. The extent of areal coverage and abundance of *Lithophyllum insipidum* are very similar to that of *P. onkodes* in the Recent Ryukyu Islands (Iryu and Matsuda, 1988). Later observation reveals, however, that this species grows rarely at depths from 20 to 30 m in the Ryukyu Islands. In Hawaii, a few specimens of this species were found from a 15 to 35 m depth range, although it is principally a shallow-water species (Adey *et al.*, 1982). Consequently, it seems that *L. insipidum* is not a suitable species to use as a depth indicator for the Ryukyu Group. Assemblage A is thought to have been distributed in depths down to 20 m. The assemblage, which is indicative of the moat environment, was expected to be distinguishable from the Assemblage A on the basis of occurrence of *Neogoniolithon frutescens* which grows abundantly and whose habitat is restricted within the moat area of the present-day Ryukyu Islands. This has not been realized because an *in situ* thallus of *N. frutescens* has not been found from the Ryukyu Group.

In Assemblage B, *P. onkodes* is totally lacking and *Neogoniolithon fosliei* or *Spongites* sp. A is found instead (Figure 9). *Spongites* sp. A is abundant at depths from 0 to 25 m and is rarely observed to a depth of 30 m in the Recent Ryukyu Islands. This is synonymous with at least a part of *N. fosliei sensu Adey et al.* (1982) which is restricted to depths less than 25 m in Hawaiian reefs. However, this species is not so abundant in the Pleistocene as in the Recent Ryukyu Islands. *N. fosliei*, which occurs abundantly in the Ryukyu Group, is also selected as a depth indicator. Gordon *et al.* (1976) recorded it to depths of 35 m in Guam. Assemblage B is considered to have existed at depths from 20 to 35 m.

Assemblage C is composed of species having a wide depth range, such as *Lithophyllum*

tesellatum, *Lithothamnion funafutiense* and branched forms of *Lithophyllum* spp. (Figure 10). The absence of *P. onkodes*, *N. fosliei* and *Spongites* sp. A characterizes Assemblage C and indicates that this assemblage was distributed at depths greater than 35 m. Rhodoliths are not found from the outcrop where Assemblage C is observed. In the modern Ryukyu Islands, rhodoliths are found from deep foreereef regions exceeding 50 m in depth, where they are distributed sporadically. It is highly probable that this assemblage existed in the depth range from 35 to 50 m or deeper.

Assemblage D is also composed of wide-depth-range species and lacks *P. onkodes*, *N. fosliei*, and *Spongites* sp. A. It is distinguished from Assemblage C in that *Lithothamnion australe* occurs in association with *Lithothamnion* sp. A. In the stratigraphic section characterized by Assemblage D, rhodoliths are sporadically scattered in outcrop. *Lithothamnion australe* is distributed at depths greater than 30 m and occurs very frequently at depths greater than 60 m in Hawaii (Adey *et al.*, 1982). It is thought that Assemblage D existed in the deep foreereef environment, exceeding 50 m depth, where hermatypic corals were highly reduced in number and abundance was replaced by rhodoliths (Table 2).

Comparison with Coral communities

Nakamori (1986) recognized five fossil coral communities (Communities A, B, C, D and E) in the coral limestone of the Ryukyu Group based on generic comparison and sedimentological features. Community A was thought to have been distributed in the moat to the reef crest of the fringing reef or in the protected shallow water of patch reefs. Community B was considered to have existed in the reef edge which stood at almost sea level. The Communities C, D, and E were interpreted as inhabiting water depths from 0 to 15 m, from 10 to 30 m, and from 30 to 100 m on the reef slope, respectively. In order to compare the bathymetric interpretations der-

ived from coralline algae and corals, fossil coralline algae were collected from nine outcrops on Okierabu-jima and nine on Kikaijima from which Nakamori (1986) examined fossil corals. The depositional environments determined by the algae accord well with those based on corals at 13 localities (Table 3), but there are disagreements amongst the remaining five outcrops. This is because the algal Assemblage C indicates environments deeper than those suggested by the corals (E10, K2, K3 and K8). Assemblage C is discriminated by negative evidence; namely three shallow (*P. onkodes*, *Spongites* sp. A, and *N. fosliei*) and two deep (*L. australe* and *Lithothamnion* sp. A) water algal species are not observed. Because the 35 to 50 m depth range, where Assemblage C is considered to have been situated, is beyond the safety limit of conventional SCUBA diving, ecologic information available on living corallines may not necessarily be sufficient to provide accurate distributional data. The coralline bathymeter should be improved in this respect. It is concluded that the depositional environments indicated by algae generally agree with those based on corals and that the fossil corallines can be as excellent depth indicators as corals.

Comparison with Foraminiferal assemblages

Noda (1976) discriminated three benthic foraminiferal assemblages (Assemblages A, B and C) in the Ryukyu Group on Yoron-jima. He stated that the Assemblage A characterized an "off-reef floor facies" and the Assemblages B and C a "reef facies". But no quantitative bathymetric data were given for each assemblage. This makes it difficult to compare quantitatively bathymetric interpretations derived from foraminifera and coralline algae. However, the fact that their interpretations agree can be verified qualitatively by comparing the distributional patterns of the flora and fauna. The foraminiferal assemblages are distributed nearly concentrically: Assemblage C occurs in an area around Ritcho where the basement rocks are exposed

at present; areas of Assemblages B and A surround the Assemblage C area successively. The distribution of the coralline-algal assemblages is highly concordant with that of foraminifera. In other words, these floral assemblages are also distributed more or less concentrically. Assemblages B and C are distributed around the area of Assemblage A. Therefore, paleoenvironments determined by the nonarticulated coralline algal assemblage do not contradict those suggested by benthic foraminifera.

Discussion

Although nonarticulated coralline algae are distributed from tropical to boreal latitudes and from intertidal to more than 200 m depths in the modern marine environment, many geoscientists considered them to be tropical shallow-water organisms. Adey and MacIntyre (1973) pointed out such misunderstandings and gave principles for paleoecologic interpretation based on the coralline algae. An increasing number of studies since the 1960's on the coralline population and zonation, coupled with works on systematics, in northern waters (Adey, 1966; Adey *et al.*, 1976) and in the tropics (Lee, 1967; Littler, 1973a, 1973b; Littler and Doty, 1975; Gordon *et al.*, 1976; Adey *et al.*, 1982; Minnerly, 1990) have shown that the ecologic specificity of many coralline taxa and morphological groups. This indicates the great potential of the coralline algae as paleoenvironmental indicators. In particular, paleontologists have paid attention to ecologic specificity in such things as morphology of coralline crusts and branches and generic floral composition.

The coralline growth form, in particular, is thought to be indicative of paleoenvironment, especially hydraulic energy, based on the following two relationships observed in the present-day marine environment:

(1) The branching of the thallus increases with increasing turbulence, namely, densely

branched forms are found in turbulent areas and open-branched forms in quiet areas. In such cases, the apices of the branches of dense forms grow laterally, in response to abrasion, and fuse with adjacent branches to form an algal nodule called a rhodolith (Bosellini and Ginsburg, 1971; Bosence, 1976, 1983; 1985a).

(2) The high-energy coralline-algal frameworks are constructed from closely superposed thick crusts and mutually fused thickly branched thalli, whereas those from sheltered environments are more delicate and open in their construction, being composed of thinner branches and crusts (Bosence, 1985b). The subtidal zonation according to coralline morphologies growing on stable substrata in tropical and nontropical regions made by Steneck (1986) indicates that thick forms predominate over thin ones at shallower depths while the reverse relationship is observed in deeper waters.

These relationships were used to determine hydraulic conditions of coralline algal bioherms and biostromes by Studencki (1979) and Bosence and Pedley (1982). However, these observations are not adopted in this study. The relationship (1) is considered inadequate to adopt because of the following two reasons. Firstly, this relationship is applicable to algal-related sediments containing many *in-situ* thalli of branched species of nonarticulated coralline algae. Such autochthonous thalli occur less abundantly in the Ryukyu Group and thus the relationship is of little use for this group. Secondly, it is still uncertain whether the branching species found from the Ryukyu Group, such as *Porolithon* sp. A, *Lithophyllum* spp., and *Mesophyllum erubescens*, show a similar relationship between branch morphology and hydraulic conditions such as exists in the modern marine environment. My observation of living corallines in the reefs of the Ryukyu Islands shows that the branch morphology of *Porolithon* sp. A and *Lithophyllum pallescens* is highly stable. This means

that the relationship (1) does not hold well in all the branched coralline species. The relationship (2) seems to show a general and rough relationship between the morphology of corallines forming frameworks and hydraulic conditions or depth and to have many exceptions. I can give the following example as disproof. In the reefs of the modern Ryukyu Islands, it is common that the thick-crustose species, such as *Neogoniolithon fosliei* and *Spongites* sp. A, are closely superposed to form thick robust frameworks at around 15 m depth on the reef slope, whereas thin and leafy corallines inhabit the basal dead portion of the dendroidal hermatypic corals to form a delicate and open framework on the more turbulent outer and inner reef flats. This evidence does conflict with the relationship (2). Consequently, the relationship (2) also can not be used for establishing the kind of paleoenvironmental interpretation attempted in this study.

The floral composition at generic level has been used for delineating paleobathymetry of algal-related deposits (Jones and Hunter, 1991). A schematic chart given by Adey (1979) and Adey *et al.* (1982) representing the relative abundance of coralline genera with respect to depth given has been used as a working standard for paleobathymetry in such studies. However, Adey (*op. cit.*) defined neither assemblages nor zones relative to specific depth ranges. Workers, therefore, had to interpret the paleobathymetry of algal-related deposits, the object of their own studies, by comparing their floral composition with Adey's scheme. This will possibly lead the workers to more or less arbitrary interpretations. Actually, Mankiewicz (1988) pointed out the occurrence of the *in-situ* branching *Mesophyllum* as one of the important documentation for the determination of water depth at the time of *Halimeda* accumulation; she stated that "Adey *et al.* (1982) showed that in modern (Atlantic) reef environments, *Mesophyllum* typically occurs in water depths greater than 50 to 60 m."

This figure ignores the fact that the branching *Mesophyllum* species, such as *M. erubescens* and *M. canariense*, are distributed at shallower depths in the Atlantic and thus seems to be arbitrary. Therefore, I have presented a stricter delineation of fossil assemblages and their specific depth ranges to avoid such vagueness.

The coralline bathymeter proposed in this paper is likely to be applicable to the Pleistocene reef limestones in the broader Indo-Pacific region, because most of the species used for the delineation of the assemblages, such as *Porolithon onkodes*, *Neogoniolithon fosliei* and *Lithothamnion australe*, have a wide geographic distribution in modern marine environment and are thought to have a similar distribution in Pleistocene time. In summary, my study indicates that the fossil coralline-algal assemblages provide a reasonable paleobathymetric information on the depths of deposition of the Pleistocene reef-limestone complex.

Conclusions

Four fossil nonarticulated coralline algal species assemblages were discriminated from the coral limestone sequence of the Pleistocene Ryukyu Group. Each assemblage indicates a specific depth range.

Paleoenvironments inferred from these algal assemblages accord well with those derived from coral communities and benthic foraminifera. It is considered that the nonarticulated coralline algae are excellent depth indicators, and we can reconstruct detailed paleoenvironments by applying the coralline bathymeter.

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References

- Adey, W.H., 1966: Distribution of saxicolous crustose corallines in the northwestern North Atlantic. *Jour. Phycol.*, vol. 2, p. 49-54.
- , 1970: A revision of the Foslie crustose coralline herbarium. *Det Kong. Vidensk. Selsk., Skrif.*, no. 1 (annual volume in 1970), p. 1-46.
- , 1979: Crustose coralline algae as microenvironmental indicators for the Tertiary. In, Gray, J. and Boucot, A.J., eds., *Historical biogeography, plate tectonics and the changing environment*, p. 459-464. Oregon State Univ. Press, Corvallis.
- , and MacIntyre, I.G., 1973: Crustose coralline algae: a re-evaluation in the geological sciences. *Geol. Soc. Amer., Bull.*, vol. 84, p. 883-904.
- , Masaki, T. and Akioka, H., 1976: The distribution of crustose corallines in eastern Hokkaido and the biogeographic relationships of the flora. *Bull. Fac. Fish. Hokkaido Univ.*, vol. 26, p. 303-313.
- , Townsend, R.A. and Boykins, W.T., 1982: The crustose coralline algae (Rhodophyta: Corallinaceae) of the Hawaiian Islands. *Smithsonian Contr. Mar. Sci.*, no. 15, p. 1-74.
- Bosellini, A. and Ginsburg, R.N., 1971: Form and internal structure of Recent algal nodules (rhodolites) from Bermuda. *Jour. Geol.*, vol. 79, p. 669-682.
- Bosence, D.W.J., 1976: Ecological studies on two unattached coralline algae from western Ireland. *Palaeontology*, vol. 19, p. 365-395.
- , 1983: Coralline algal frameworks. *Jour. Geol. Soc. London*, vol. 140, p. 365-376.
- , 1985a: The morphology and ecology of a mound-building coralline alga (*Neogoniolithon strictum*) from the Florida Keys. *Palaeontology*, vol. 28, p. 189-206.
- , 1985b: Preservation of coralline-algal frameworks. *Proc. 5th Int. Coral Reef Congr., Tahiti*, vol. 6, p. 623-628.
- and Pedley, H.M., 1982: Sedimentology and paleoecology of a Miocene coralline algal biostrome from the Maltese Island. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, vol. 38, p. 9-43.
- Campbell, S.J. and Woelkerling, Wm. J., 1990: Are *Titanoderma* and *Lithophyllum* (Corallinaceae, Rhodophyta) distinct genera? *Phycologia*, vol. 29, p. 114-125.
- Foslie, M.H., 1929: *Contribution to a monograph of the Lithothamnia*. 60p. Det Kong. Selsk. Vidensk. Mus., Trondheim (after the author's death, collected and edited by Printz, H.).
- Gordon, G.D., Masaki, T. and Akioka, H., 1976: Floristic and distributional account of the common crustose coralline algae on Guam. *Micronesica*, vol. 12, p. 247-277.
- Heydrich, F., 1900: Eine neue fossile Alge aus Riukiu, *L. nahaense* sp. nov. *Jour. Geol. Soc. Japan.*, vol. 7, unpaged.
- Iryu, Y., 1984: Discovery of Recent deep water rhodoliths from the Ryukyu Islands, southwestern Japan, and its significance. *Prompt Rep. Compreh. Sci. Surv. Ryukyu Archipelago*, no. 1, p. 47-55. (in Japanese with English abstract)
- , 1985: Study on the Recent rhodoliths around the Ryukyu Islands. *Ibid.*, no. 2, p. 123-133. (in Japanese with English abstract)
- , 1986: Litho- and chronostratigraphy of the Ryukyu Group on Yoron-jima. *Geol. Soc. Japan, Abstracts with Programs, 93rd Ann. Meet., Yamagata*, p. 131. (in Japanese)
- , 1991a: Algae and seagrasses of coral reefs around Ishigaki Island and its adjacent area. In, Mezaki, S., ed., *The coral reefs of Ishigaki Island*, p. 73-86. WWF Japan, Tokyo. (in Japanese with English abstract)
- , 1991b: Algae and seagrasses of the coral reefs on the east of Kara-dake, Ishigaki Island, Ryukyu Islands. *Ibid.*, p. 159-171. (in Japanese with English abstract)
- and Hayasaka, S., 1985: Topography and marine sediments in a range of rhodoliths. *Prompt Rep. Compreh. Sci. Surv. Ryukyu Archipelago*, no. 2, p. 117-121. (in Japanese with English abstract)
- and Matsuda, S., 1987: Distribution of nonarticulated coralline algae in the reef environment of the Ryukyu Islands. *Kaiyo-kagaku*, vol. 19, p. 524-529. (in Japanese)
- and —, 1988: Depth distribution, abundance and species assemblages of nonarticulated coralline algae in the Ryukyu Islands, southwestern Japan. *Proc. 6th Int. Coral Reef Symp., Townsville*, vol. 3, p. 101-106.
- , Nakamori, T. and Yamada, T., 1992: A unit of lithostratigraphic classification of the Ryukyu

- Group, Pleistocene reef complex deposits. *Jour. Sedimentol. Soc. Japan*, no. 36, p. 57-66. (in Japanese with English abstract)
- , and Yamada, T., 1991: A preliminary report on Pleistocene sea level changes recorded in the Ryukyu Group on Toku-no-shima and Okierabu-jima, Ryukyu Islands. In, Professor Hisao Nakagawa Taikan Kinenjigyo-kai, ed., *Essays in Geology (Professor Hisao Nakagawa Commemorative Volume)*, p. 73-83. Toko Printing Co. Ltd., Sendai. (in Japanese with English abstract)
- Ishijima, W., 1938: New species of calcareous algae from several Tertiary and later limestone of the Ryukyu Islands. *Japan. Jour. Geol. Geogr.*, vol. 15, p. 13-16.
- , 1942a: On the coralline algae from the Ryukyu Limestone of Kotosho (Botel Tobago Island). *Taiwan Chigaku-kiji*, vol. 13, nos. 2-3, p. 78-84. (in Japanese)
- , 1942b: Fossil *Lithoporella* and its classification. *Ibid.*, vol. 13, no. 4, p. 2-12. (in Japanese with English systematic description)
- , 1944: On some fossil coralline algae from the Ryukyu Limestone of the Ryukyu Islands and Formosa (Taiwan). *Mem. Fac. Sci. Taihoku Univ., Ser. III*, vol. 1, p. 49-76.
- , 1954: *Cenozoic coralline algae from the Western Pacific*. 87 p. Yuho-do, Tokyo.
- Jones, B. and Hunter, I.G., 1991: Corals to rhodolites to microbialites—a community replacement sequence indicative of regressive conditions. *Palaios*, vol. 6, p. 54-66.
- Lee, R.S.K., 1967: Taxonomy and distribution of the melobesoid algae on Rongelap Atoll, Marshall Islands. *Canad. Jour. Bot.*, vol. 45, p. 985-1001.
- Lemoine, P., 1911: Structure anatomique des Mélobésiées. Application à la classification. *Ann. l'Inst. Océanogr.*, tome 2, p. 1-213.
- Littler, M.M., 1973a: The distribution, abundance and communities of deep water Hawaiian crustose Corallinaceae (Rhodophyta, Cryptonemiales). *Pac. Sci.*, vol. 27, p. 281-289.
- , 1973b: The distribution and community structure of Hawaiian fringing reef crustose Corallinaceae. *Jour. Exp. Mar. Biol. Ecol.*, vol. 11, p. 103-120.
- and Doty, M.S., 1975: Ecological components structuring the seaward edges of tropical Pacific reefs: the distribution, communities and productivity of Porolithon. *Jour. Ecol.*, vol. 63, p. 117-129.
- Mankiewicz, C., 1988: Occurrence and paleoecologic significance of *Halimeda* in late Miocene reefs, southern Spain. *Coral Reefs*, vol. 6, p. 271-79.
- Matsuda, S., 1987: Nonarticulated coralline algae in the Ryukyu Islands. *Kaiyo-Kagaku*, vol. 9, p. 162-167. (in Japanese)
- , 1989: Succession and growth rates of encrusting crustose coralline algae (Rhodophyta, Cryptonemiales) in upper fore-reef environment off Ishigaki Island, Ryukyu Islands. *Coral Reefs*, vol. 7, p. 185-195.
- and Tomiyama, T., 1988: An investigation of Recent deepwater rhodoliths from the Ryukyu Islands. *Bull. Coll. Educ. Univ. Ryukyus*, no. 33, p. 343-354. (in Japanese with English abstract)
- , Iryu, Y. and Nohara, M., 1992 (in press): Rhodoliths on the deep forereef of Okinawajima, Ryukyu Islands. *Jour. Sedimentol. Soc. Japan*, no. 37. (in Japanese)
- Minnery, G.A., 1990: Crustose coralline algae from the Flower Garden Banks, northwestern Gulf of Mexico: controls on distribution and growth morphology. *Jour. Sed. Petrol.*, vol. 60, p. 992-1007.
- Minoura, K., 1979a: Sedimentological study of Ryukyu Group. *Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.)*, vol. 49, p. 1-70.
- , 1979b: Depositional environment of algal balls of the Ryukyu Group. *Geol. Stud. Ryukyu Islands*, vol. 4, p. 55-62. (in Japanese with English abstract)
- and Nakamori, T., 1982: Depositional environment of algal balls in the Ryukyu Group, Ryukyu Islands, southwestern Japan. *Jour. Geol.*, vol. 90, p. 602-609.
- Nakamori, T., 1986: Community structure of Recent and Pleistocene Hermatypic corals in the Ryukyu Islands, Japan. *Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.)*, vol. 56, p. 71-133.
- Noda, M., 1976: Ryukyu Limestone of Yoron-to (Yoron Island). *Jour. Geol. Soc. Japan*, vol. 82, p. 367-381. (in Japanese with English abstract)
- Nohara, M., Ohshima, K., Yokota, S., Murakami, F., Iuchi, Y. and Ikeda, K., 1979: Marine sediments from the adjacent sea around the Okinawa Islands. *Environmental Research in Japan*, vol. 2 (annual volume in 1979), p. 3-28. (in Japanese with English abstract)
- Penrose, D. and Woelkerling, Wm. J., 1988: A taxonomic reassessment of *Hydrolithon* Foslie, *Porolithon* Foslie, and *Pseudolithophyllum* Lemoine emend. Adey (Corallinaceae, Rhodophyta) and their relationships to *Spongites* Kützing. *Phycologia*, vol. 27, p. 159-176.
- Studencki, W., 1979: Sedimentation of algal limestones from Busko-Spa environs (Middle Miocene, Central Poland). *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, vol. 27, p. 155-165.
- Tsuji, Y., Sunouchi, H., Yamamura, T., Kodato, T., Yuki, T. and Iwamoto, H., 1989: Recent marine

sediments and their depositional environments,
to the west of Miyako-jima, Ryukyu Islands.
Chikyū, vol. 11, p. 612-617. (in Japanese)

Woelkerling, Wm. J., 1988: *The coralline red algae*.
268 p. Oxford Univ. Press, London.

Akazaki 赤崎, Araki 荒木, Asado 朝戸, Chabana 茶花, China 知名, Furusato 古里, Goran 後蘭, Gusuku 城, Higashi-ku 東区, Hyakunodai 百之台, Inutabu 犬田布, Itokina 糸木名, Kikai-jima 喜界島, Nagamine 永嶺, Nama 那間, Nishi 仁志, Okidomari 沖泊, Okierabu-jima 沖永良部島, O-yama 大山, Ritcho 立長, Sakibaru 崎原, Serikaku 瀬利覚, Shimohirakawa 下平川, Shimoshiro 下城, Shinjo 新城, Somachi 早町, Sumiyoshi 住吉, Tamina 田皆, Takigawa 滝川, Toku-no-shima 徳之島, Tomori 供利, Wan 湾, Yaja 屋者, Yakomo 屋子母, Yoron-jima 与論島.

琉球層群の古水深指標としての無節サンゴモ：琉球列島の与論島、沖永良部島、徳之島、喜界島に分布する第四系琉球層群中の無節サンゴモ化石を検討した。現在の琉球列島周辺海域における無節サンゴモとの比較から、同層群中に4つの化石無節サンゴモ群落を識別し、それぞれの化石群落の分布深度を推定した。化石無節サンゴモ群落の示す古水深は、化石サンゴ群集による推定古水深とほぼ調和的であり、化石無節サンゴモが古環境、特に古水深の指標として有用であることが判明した。 井龍康文

941. LOWER AND MIDDLE TRIASSIC RADIOLARIANS FROM MT. KINKAZAN, GIFU PREFECTURE, CENTRAL JAPAN*

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Abstract. Well-preserved radiolarians have been obtained from the Lower and Middle Triassic in Mt. Kinkazan, Gifu City, Gifu Prefecture, central Japan. They are represented by three assemblages, namely the *Parentactinia nakatsugawaensis* assemblage (Spathian or older), *Hozmadia gifuensis* sp. nov. assemblage (early Anisian) and *Triassocampe coronata* assemblage (middle Anisian). On the basis of field observations, radiolarian dating and some sedimentological examinations, the general stratigraphy in the studied area is tentatively reconstructed as a sequence of Lower Triassic black shale, siliceous shale to chert, and Middle Triassic bedded chert in ascending order. The occurrence of Permian radiolarians in the studied area is also discussed. Twenty-six species are newly described and four new genera are also proposed herein.

Key words. Radiolaria, Lower to Middle Triassic, Mt. Kinkazan, Gifu Prefecture, central Japan

Introduction

A large amount of knowledge concerning late Anisian to Rhaetian radiolarians has been accumulated chiefly in European Tethyan region (e.g. De Wever *et al.*, 1979; Dumitrica, 1978a, 1978b, 1982a, 1982b, 1982c; Dumitrica *et al.*, 1980; Kozur and Mostler, 1972, 1978, 1979, 1981, Lahm, 1984), western North American region (e.g. Pessagno and Blome 1980; Pessagno *et al.*, 1979; Blome, 1983, 1984; Yeh, 1989) and western Pacific region (e.g. Nakaseko and Nishimura, 1979; Yao, 1982; Yao *et al.*, 1980; Cheng, 1989; Blome *et al.*, 1987, Yeh, 1990). Thus, it appears that now we have enough faunal information to reconstruct the phylogenetic relationship between the Triassic and Jurassic radiolarians.

On the other side, recent progress of research on radiolarians has revealed rich

components of Permian radiolarian faunas (e.g. Ishiga *et al.* 1982a, 1982b; Kozur and Mostler, 1989; Nazarov and Ormiston, 1985). Complete lack of the information of radiolarian fossils near the Permo-Triassic boundary, however, prevents our precise tracing of the evolutionary lineages across the P-T boundary. Therefore, what effect the most severe mass extinction during the Phanerozoic time had on radiolarian phylogeny remains an unsolved problem.

The P-T boundary is also very interesting geologically because many paleoenvironmental problems at that time remain unsolved. This situation is applicable to the Paleozoic-Mesozoic sedimentary complex in Japan, such as the Mino and Chichibu Terranes, and it seems mainly due to our insufficient knowledge about the Lower Triassic.

In order to clarify the above-mentioned taxonomic and geologic problems, I have performed detailed field investigation in Mt.

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Kinkazan, Gifu Prefecture, central Japan, from which Ando (1987) reported the occurrence of Middle Triassic to Early Jurassic radiolarians in chert beds and Middle to Late Permian radiolarians in siliceous shale beds. He also reported the occurrence of siliceous rocks which yield Early Triassic spicular radiolarians described by Sashida (1983). I have reexamined this area and collected more than 1,000 rock samples of black shale, siliceous shale and chert beds abundantly bearing Permian and Early to Middle Triassic radiolarians. Consequently, many new facts have been revealed on the geology of the Lower to Middle Triassic in this area, especially mode of occurrence of Permian radiolarians, and the obtained radiolarians also permit me to develop some new ideas on radiolarian phylogeny, particularly on the phylogenetic relationship between the orders Entactinaria and Nassellaria, which Sugiyama (1990, 1991a, 1991b) has already

treated preliminarily.

The present study, as the first of a series, focuses on describing three Early to Middle Triassic radiolarian assemblages recognized so far and the characteristic component species of each assemblage, after a brief mention of the geologic setting.

Geologic setting

Mt. Kinkazan, located approximately at the center of Gifu City, consists of dominant chert beds with subordinate amount of black shale, siliceous shale and sandstone beds. It lies on the southern margin of the Mino Terrane which is composed of the Paleozoic-Mesozoic sedimentary complexes of sandstone, shale, chert, limestone and greenstone (Mizutani, 1990), and belongs to the Complex 3 of Otsuka (1988) and Kamiaso Unit of Wakita (1988). I have made a detailed field investigation and sampling along routes A, B

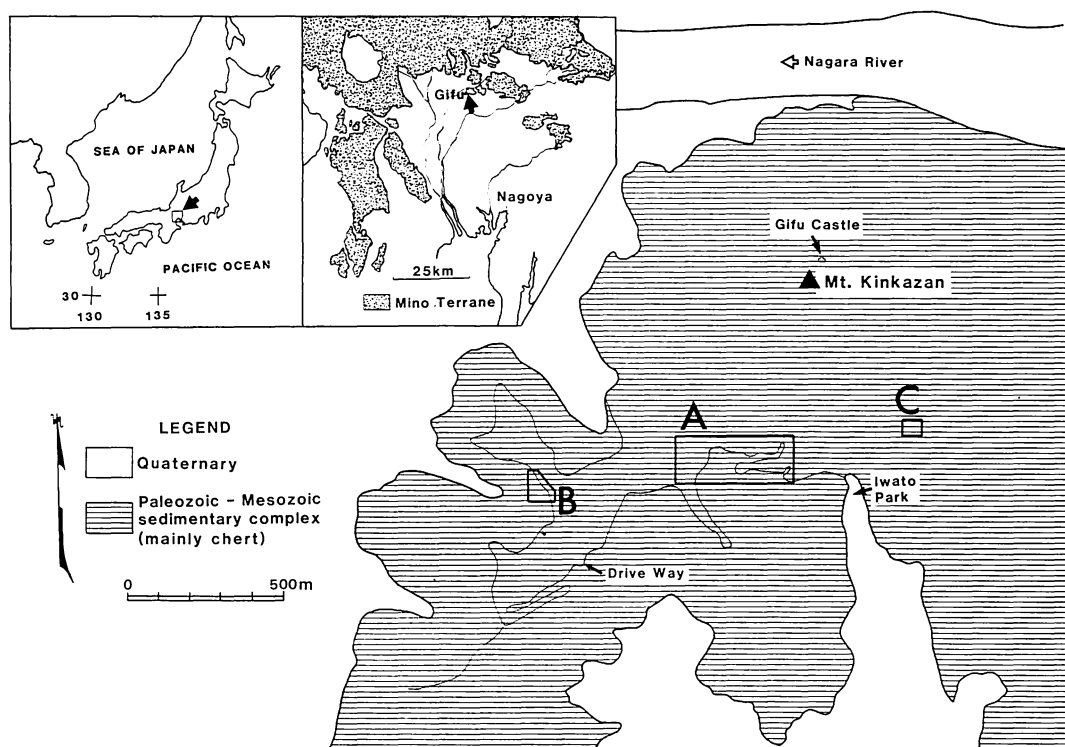


Figure 1. Index map showing the localities of three routes A, B and C.

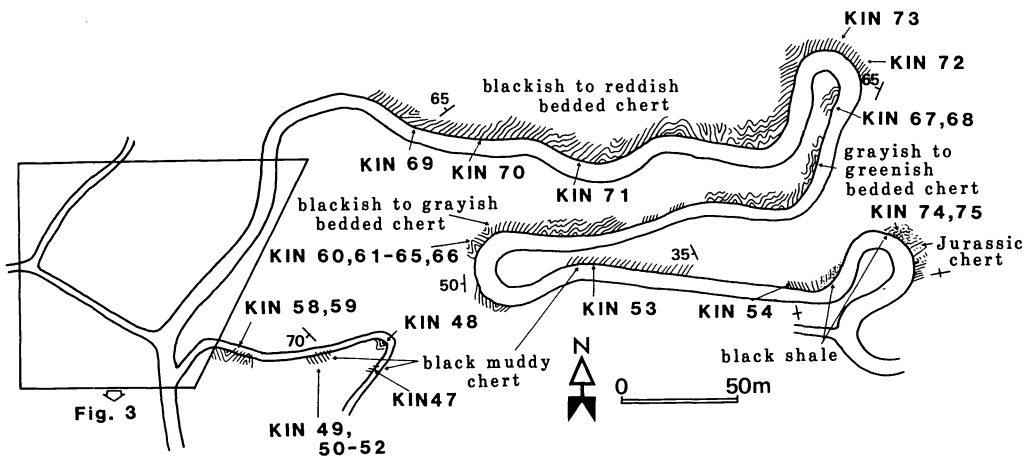


Figure 2. Route map of the route A, also showing the sampling locations (KIN). Hyphenated numbers mean that they were obtained from a continuous sections.

and C (Figs. 1-3). Route A includes, Localities 2 and 3 of Ando *et al.* (1991), whereas routes B and C contain their Localities 1 and 4, respectively. I can unfortunately deal only with route A in this study as a detailed discussion is beyond the scope of this paper. The results regarding the other two routes and a total discussion are hoped to be published in the near future.

In route A, bedded chert with a small amount of black shale and siliceous shale beds are well exposed along the roadcuts. They are complicatedly folded and have some minor faults. Chert beds have considerable variation in color, from black, gray, and green to red. Reddish chert is restricted in the distribution to the northern-northeastern part of this route; in contrast, grayish to blackish chert predominates in the southern part of the route. Blackish chert is rather muddy and usually grades into black to blackish gray, bedded siliceous shale. This type of bedded chert is termed black muddy chert in this study. The central part of the route is almost entirely occupied by greenish to grayish chert. Moreover, black shale and relatively massive siliceous shale to chert outcrop in some places.

Well-preserved late Middle to early Late Permian and Early to Middle Triassic

radiolarians have been obtained from this route. As a result of the examination of principal species composition, four radiolarian assemblages, one Permian and the others Triassic, have been recognized. The Permian radiolarian assemblage is characterized by abundant occurrence of *Follicucullus scholasticus* Ormiston and Babcock. *F. monacanthus* Ishiga and Imoto was also obtained from the sample KIN 28. The age is thus late Middle to early Late Permian, according to Ishiga (1986). Triassic radiolarian assemblages are newly discriminated in this study, and named *Parantactinia nakatsugawaensis* (Pn) assemblage (Spathian or older), *Hozmadia gifuensis* sp. nov. (Hg) assemblage (early Anisian) and *Triassocampe coronata* (Tc) assemblage (middle Anisian) in chronologic order. The detailed definitions and characteristic species of each assemblage are fully discussed in the next chapter.

Then one can easily recognize that there is a close relationship between lithofacies and radiolarian assemblages. For example, black muddy chert yields representative species of the Pn assemblage and so on. It is consequently suggested that differences of lithofacies reflect differences of age, and the general stratigraphy of route A is roughly

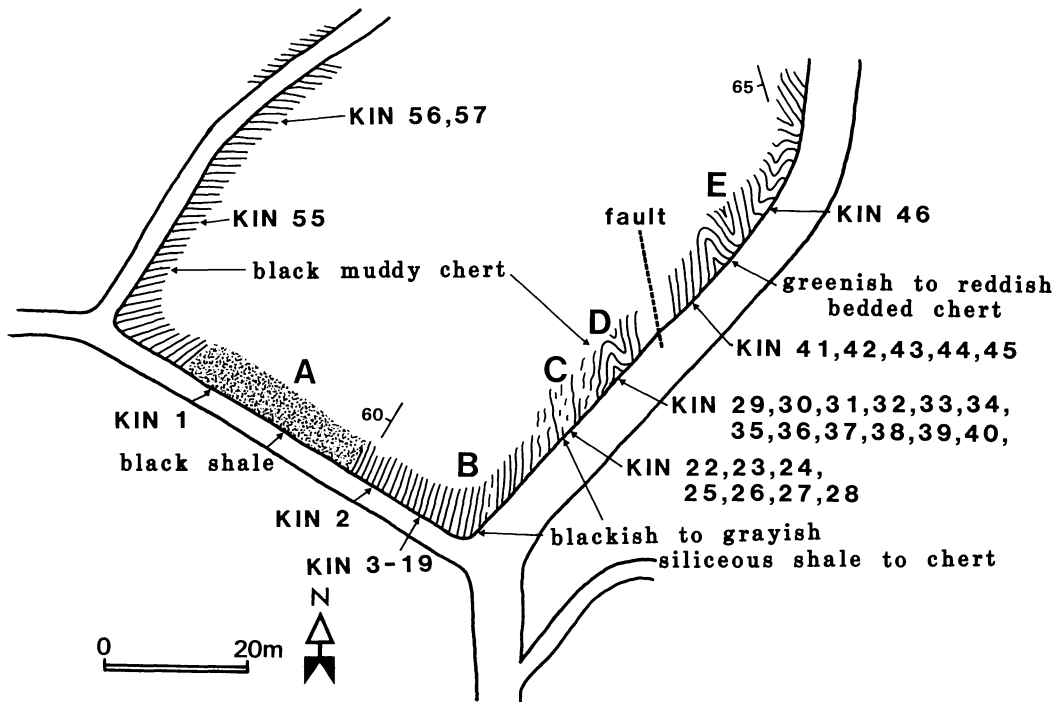


Figure 3. Enlargement of the western part of the route A.

reconstructed as a sequence of black muddy chert, grayish to greenish bedded chert and greenish to reddish bedded chert in ascending order from Spathian to middle Anisian interval.

The development of other lithofacies and their relationship to the occurrence of Permian radiolarians remains uncertain. It is noteworthy that Permian radiolarians from Mt. Kinkazan area sometimes exhibit peculiar overlaps which strongly conflict with their previously known chronologic ranges, as mentioned by Ando *et al.* (1991). Besides such a fact, personal investigations have proved that they can co-occur even with Triassic radiolarians in a single sample. In order to clarify the problem, I describe in the following lines the detailed litho- and biostratigraphy in the part of route A shown in Figure 3, which corresponds to Loc. 2 of Ando *et al.* (1991).

In Figure 3, five units are recognized based on lithology and contained fossils, and they

are conveniently called units A to E. The unit A is composed of black shale and sometimes yields poorly preserved, spherical radiolarians. This unit rarely yields molded *Follicucullus scholasticus* (KIN 1). Similar black shale beds corresponding to the Loc. 3 of Ando *et al.* (1991), exposed in the eastern part of route A in fault contact with the Jurassic chert beds, also yield some Permian radiolarians such as *F. scholasticus*, *Pseudotormentus kamigoriensis* De Wever and Caridroit (KIN 74 and 75). Ando *et al.* (1991) mentioned that the unit A occurs in fault contact with unit B, but the fault seems to be a negligibly small slip along the bedding plane.

The unit B is composed of blackish to grayish, sometimes greenish gray, well-stratified siliceous shale to chert. It apparently resembles "Toishi-type" shale defined by Imoto (1984) but exactly differs in its uniform content of organic remains. All the beds dip nearly 90° and no intraformational

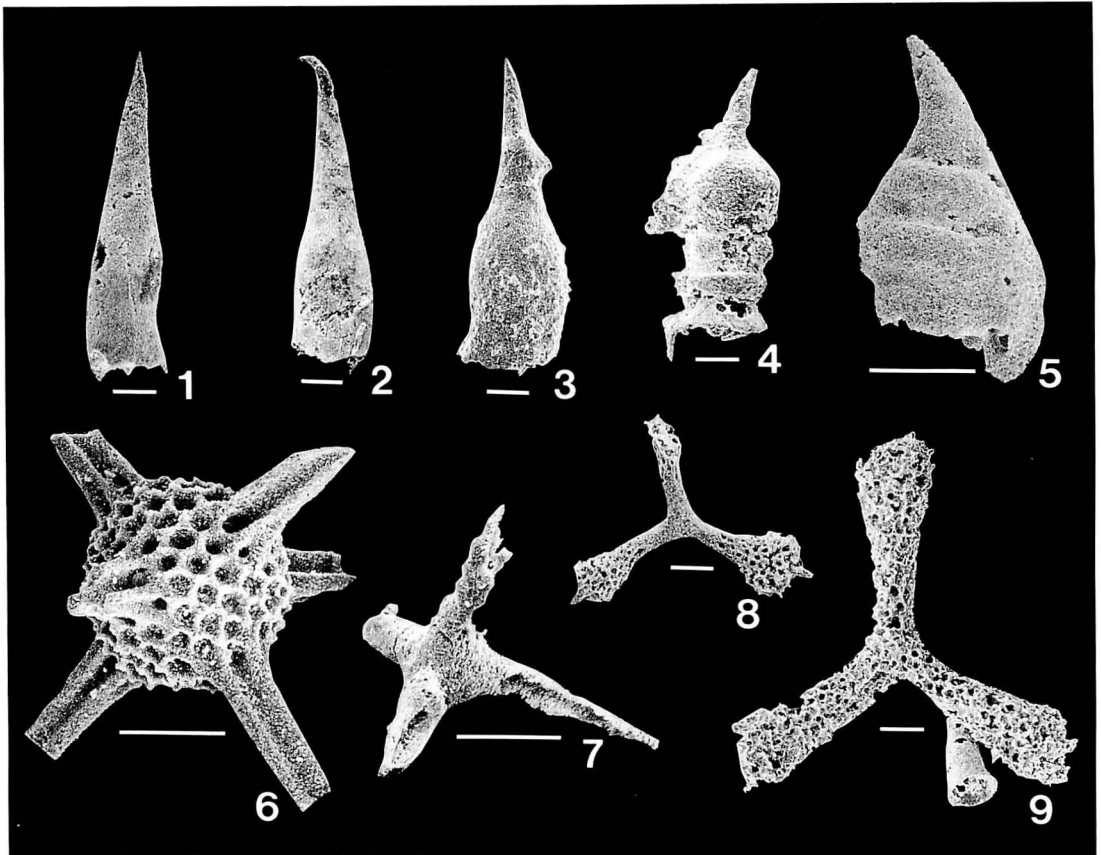


Figure 4. 1: *Follicucullus scholasticus* Ormiston and Babcock, ESN 146281, KIN 32. 2: *Follicucullus bipartitus* Caridroit and De Wever, ESN 146238, KIN 18. 3: *Follicucullus monacanthus* Ishiga and Imoto, ESN 146237, KIN 28. 4: *Pseudoalbaillella globosa* Ishiga and Imoto, ESN 146282, KIN 11. 5: *Albaillella triangularis* Ishiga, Kito and Imoto, ESN 146283, KIN 13. 6: *Entactinia* sp., ESN 146284, KIN 34. 7: *Ormistonella robusta* De Wever and Caridroit, ESN 146245, KIN 32. 8: *Ishigaum* sp., ESN 146285, KIN 22. 9: *Latentifistula* (?) sp., ESN 146286, KIN 34. All scale bar = 50 μ m.

folding is observable although some minor faults exist. Ando *et al.* (1991) reported the occurrence of only Permian radiolarians in this unit (corresponding to their Locality JMP 1334). However, I have revealed that they are commonly accompanied by the component species of the Pn assemblages and even Triassic-type conodonts. Moreover, the chronologic ranges of *P. globosa* Ishiga and Imoto and *Albaillella triangularis* Ishiga, Kito and Imoto, obtained from samples KIN 4 and 13 respectively, are restricted to the Middle Permian and Late Permian, respectively

(Ishiga, 1986).

The stratigraphic relationship between the units B, C and D is not supported by the fossil contents. The unit C is apparently massive siliceous shale to chert, and exposed, with an obscure boundary, between units B and D on a small scale. This unit contains only Permian radiolarians and correlates with the *F. monacanthus* Range-zone to *F. scholasticus* Assemblage-zone of Ishiga (1986).

Unit D is composed of black muddy chert, and yields especially well-preserved radiolarians which are representatives of the Pn

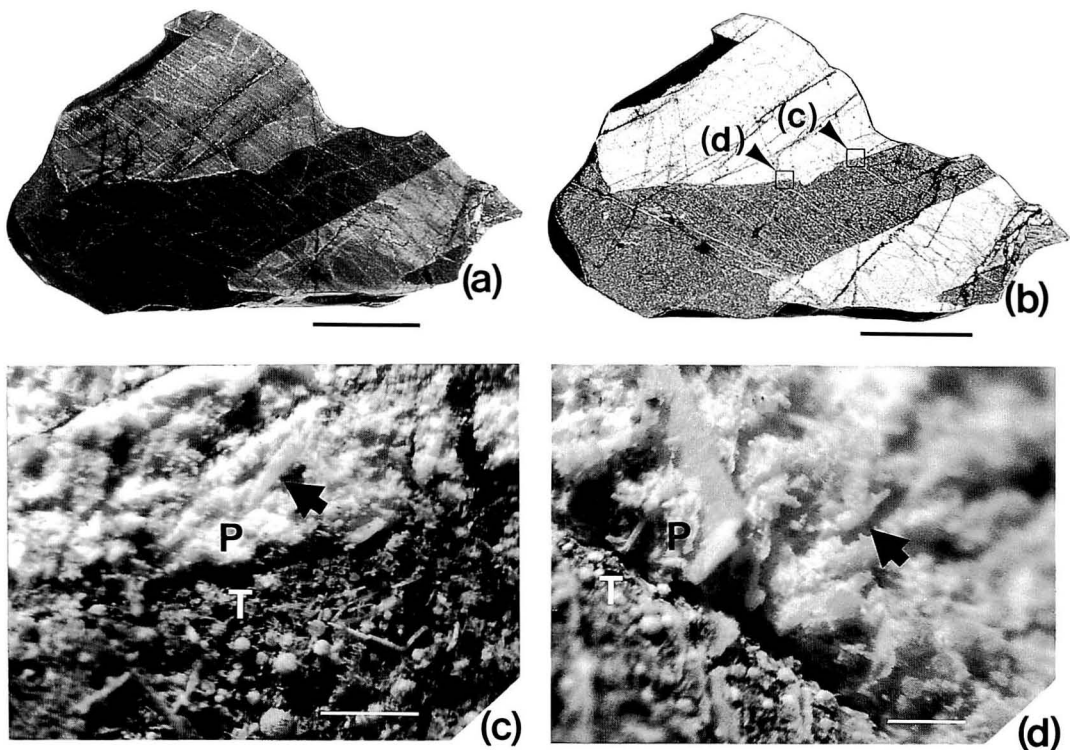


Figure 5. (a): Polished surface of the sample KIN 32. Scale bar=1 cm. (b): Etched surface of the same sample. P=Permian exotic block. T=Triassic matrix. Scale bar=1 cm. (c) and (d): Enlargements of the parts shown in (b). Scale bars=200 μm . Arrows point *Follicucullus scholasticus*.

assemblage sometimes accompanied by some Permian radiolarians which occur in the unit B. Of special interest is that some beds of this unit include a large amount of cherty exotic rocks which are commonly granule to pebble, sometimes boulder in size and visible to the naked eye (Figure 5). Observation of the etched surfaces on such peculiar beds has revealed that the component species of the Pn assemblage occur only in the matrix, whereas contained granules to pebbles yield only Permian radiolarians. The beds naturally contain much smaller, cherty clastic grains which are quite easy to observe under the microscope because they are much more siliceous than the matrix (Figure 6).

There are several meters of barren rock between the units D and E. The latter unit is composed of greenish to reddish bedded chert and characterized by the occurrence of the

members of the Tc assemblage. A fault may exist between both units because of the lack of the Hg assemblage. It is interesting that the sample KIN 44 of this unit also yields Permian radiolarians.

Except for units A and C, it is apparent from the above descriptions and Table 1 that Permian radiolarian-bearing beds can be classified into two types; (1) the beds simultaneously yielding Triassic radiolarians and (2) the beds conformably over- and underlain by Triassic radiolarian-bearing beds. The latter obviously indicates an abnormal mode of occurrence of Permian radiolarians in the Triassic beds. Concerning the former type, I must conclude that all the Permian radiolarians are either reworked fossils or from the Permian exotic rocks and clastic grains, based on the facts confirmed in the units B and D. This is the best explanation for the peculiar

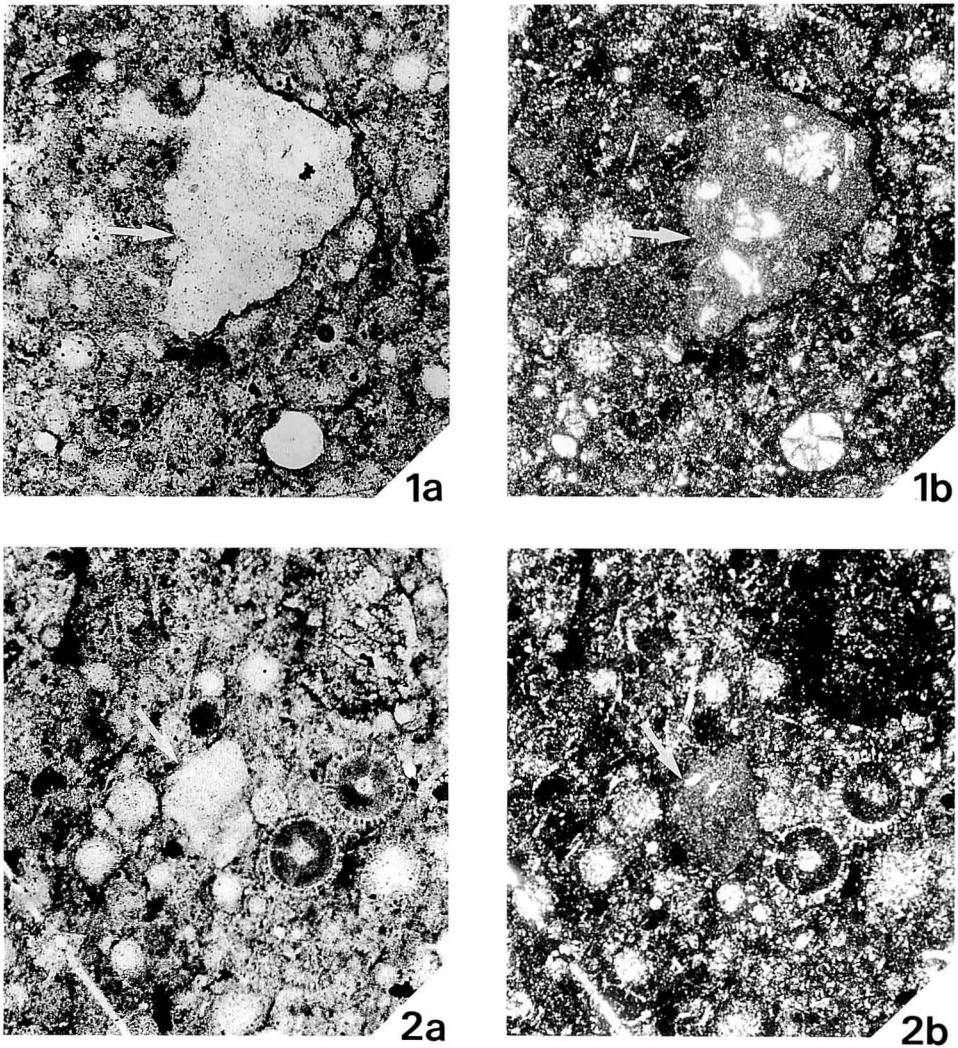


Figure 6. Photomicrographs of cherty clastic grain in the sample KIN 32. 1a and 2a ; open nicol, 1b and 2b ; closed nicols, $\times 62$.

co-occurrence of Permian radiolarians reported by Ando *et al.* (1991). The precise stratigraphic position of black shale represented by unit A is at the present time not well understood, but judging from field observations and the fossils it contains, it seems certain that its position is the lowest of all the lithofacies. Consequently, the general stratigraphy of route A is reconstructed as follows in ascending order: (1) black shale, (2) siliceous shale to black muddy chert rich in

Permian reworked fossils, with or without conspicuous exotic blocks, (3) gray to greenish-gray bedded chert and (4) greenish to reddish bedded chert (Figure 7). In this study I provisionally consider that (1) is stratigraphically just beneath (2). Unit C is regarded as an allochthonous block or blocks in the Lower Triassic.

Early to Middle Triassic radiolarian assemblages

As mentioned in the preceding chapter, three Triassic radiolarian assemblages are recognized in route A on the basis of principal species composition. They are chronologically as follows; (1) *Parentactinia nakatsugawaensis* assemblage, (2) *Hozmadia gifuensis* assemblage and (3) *Triassocampe coronata* assemblage. In the following, diagnostic species are given and the age of each assemblage is discussed.

Parentactinia nakatsugawaensis (Pn) assemblage

This assemblage is well represented by the radiolarian microfauna obtained from black muddy chert, and characterized by abundant occurrence of *Parentactinia nakatsugawaensis* Sashida. Other diagnostic species are *Hozmadia ozawai* sp. nov., *Tripedocorbis* sp. A, *Zevius yaoi* sp. nov., *Tetrarchiplagia simplex* sp. nov., *Cryptostephanidium longispinosum* (Sashida), *Pseudostylosphaera kozuri* sp. nov., *Archaeosemantis cristianensis* Dumitrica, *Parentactinia okuchichibuensis* (Sashida), *Cenosphaera andoi* sp. nov., *Pegoxystris mizutanii* sp. nov. and *Pantanelium* (?) *virgeum* Sashida. The occurrence of *Zamolxis dimitricai* sp. nov., *Tetrarhopalus itoigawai* sp. nov., *Triassobipedis* (?) *aetoides* sp. nov. and *Polyentactinia* (?) *biacus* sp. nov. are common in some samples but usually rare. The occurrence of following species is rare; *Poulpus nishimurae* sp. nov., *Zevius perarmatus* sp. nov., *Hinedorcus holdsworthi* sp. nov., *Entactinia morii* sp. nov., *Parasensagon leptaleus* sp. nov., *Parentactinia ramosus* (Sashida), *Polyentactinia* (?) *crux* sp. nov., *Pentabelus furutanii* sp. nov., *Pegoxystris* sp. A, *Tiborella agria* sp. nov. and *Plafkerium* (?) *antiquum* sp. nov. Many other indeterminate entactinarian and spumellarian species are present in this assemblage. Abundance of entactinarian species marks this assemblage, whereas nassellarian and spumellarian species are relatively rare. This assemblage

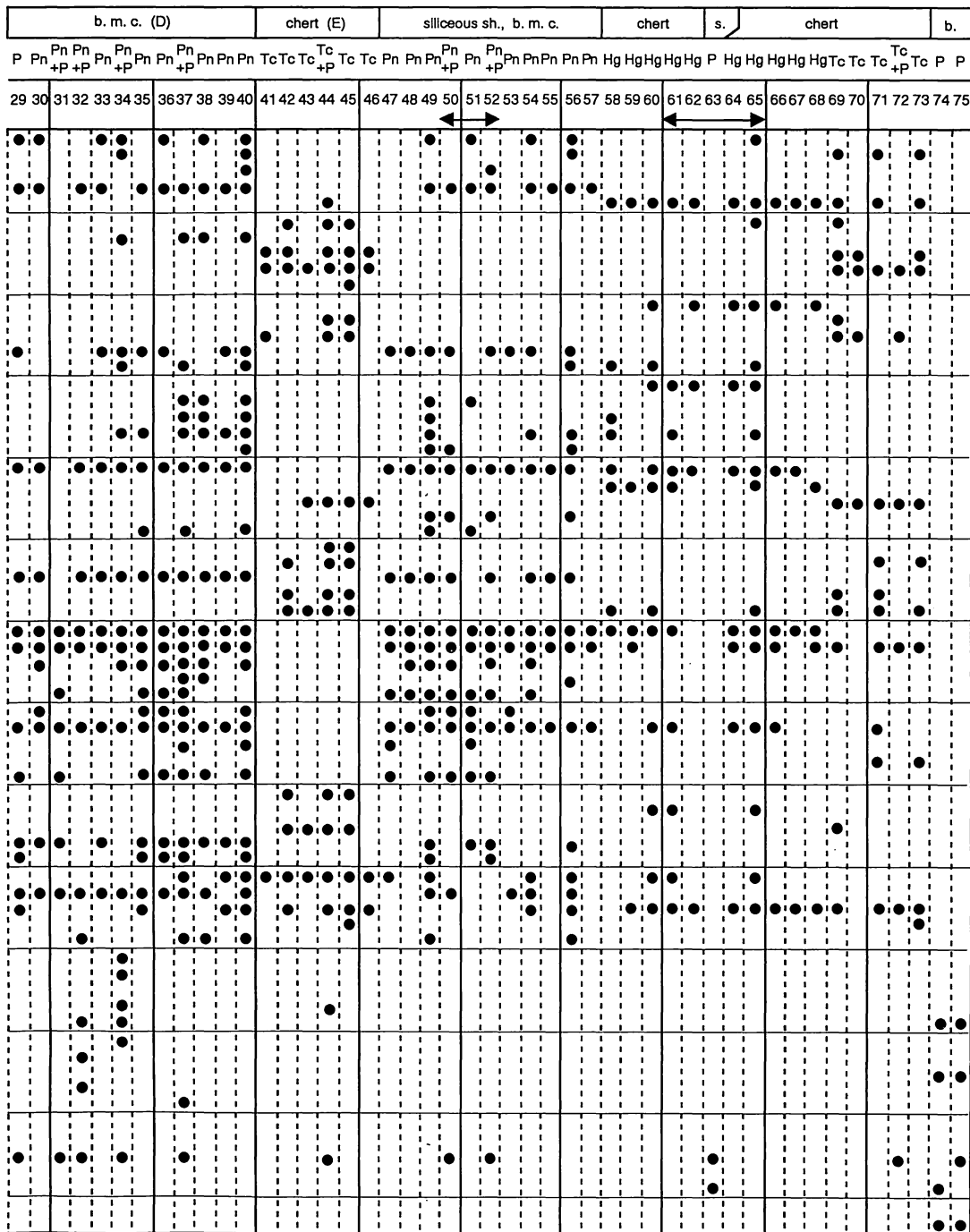
is easily distinguished from the *Hozmadia gifuensis* assemblage by lacking *H. gifuensis* sp. nov.

This assemblage contains most of the Early Triassic radiolarians described by Sashida (1983, 1991). Co-occurring conodonts from some samples represent the *Neosnathodus homeri* assemblage of Koike (1981). Accordingly the age of this assemblage is considered to be Spathian, but the lower limit is still uncertain.

Hozmadia gifuensis (Hg) assemblage

This assemblage is defined by the predominant occurrence of *Hozmadia gifuensis* sp. nov. Other characteristic species are *No-frema* (?) *gigantoceras* sp. nov., *Triassocampe* (?) sp. A, *Zevius* spp. including undescribed forms, *Cryptostephanidium longispinosum* (Sashida), *Cryptostephanidium* sp. cf. *C. verrucosum* Dumitrica, *Archaeosemantis cristianensis* Dumitrica, *Parentactinia nakatsugawaensis* Sashida, *Katorella bifurcata* Kozur and Mostler and *Plafkerium* (?) *antiquum*. Of these *C. longispinosum*, *A. cristianensis*, *P. nakatsugawaensis* and *Plafkerium* (?) *antiquum* are common to the Pn assemblage. The occurrence of the first three species in the Hg assemblage is, however, far less frequent than in the Pn assemblage, while the last species is much more frequent in this assemblage. The occurrence of *Poulpus nakasekoi* sp. nov. and spicular radiolarians such as *Tetrarchiplagia* spp. is common to rare. Moreover, many undescribed polyentactiniids (?) and oertlispongids co-occur with above mentioned species. This assemblage is distinguished from the *Triassocampe coronata* assemblage by lacking typical species of *Triassocampe*.

Although the age of this assemblage is not directly known, it is presumed to be early Anisian because of the following two reasons: (1) The specific composition indicates that the Hg assemblage is undoubtedly younger than the Pn assemblage and older than the following Tc assemblage. (2) Mat-



suda and Isozaki (1982) reported successive occurrence of Anisian radiolarians in a bedded chert sequence in the Kamiyaso area, Gifu Prefecture. It seems that early Anisian

radiolarians from their Samples A to E, dated by conodonts, are similar to the component species of the Hg assemblage.

Triassocampe coronata (Tc) assemblage

This assemblage is characterized by abundant occurrence of *Triassocampe coronata* Bragin and *T. myterocorys* sp. nov. Other characteristic species are *Hozmadia gifuensis* sp. nov., *Triassocampe* sp. aff. *T. diordinis* Bragin, *Spongosilicarmiger mostleri* sp. nov., *S. scabiturritus* sp. nov., *Eptingium manfredi* Dumitrica, *Pseudostylosphaera compacta* (Nakaseko and Nishimura), *P.* sp. A, *Cenosphaera clathrata* Parona, *Oertlispongus diacanthus* sp. nov. and *Plafkerium* (?) *antiquum*. The occurrence of *Poulpus nakasekoi*, *Tetrarchiplagia* spp., *Parasepsagon variabilis* (Nakaseko and Nishimura), *Archaeosemantis cristianensis* Dumitrica and *Parentactinia nakatsugawaensis* is common to rare. As accessory constituent species *Entactinia* (?) sp. and *Astrocentrus pulcher* Kozur and Mostler have been obtained from some samples. Moreover, indeterminable

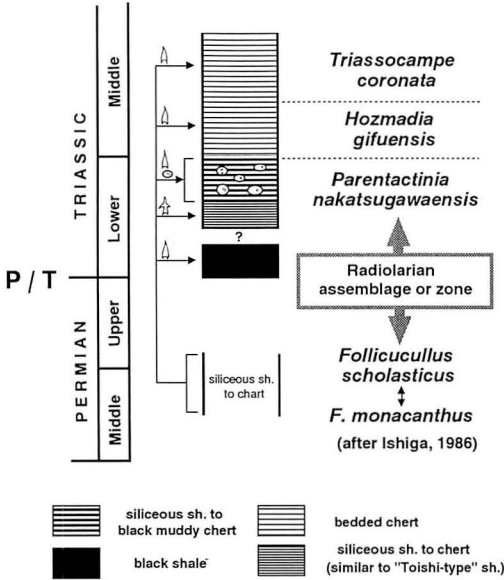


Figure 7. Schematic illustration showing reconstructed stratigraphy of the route A.

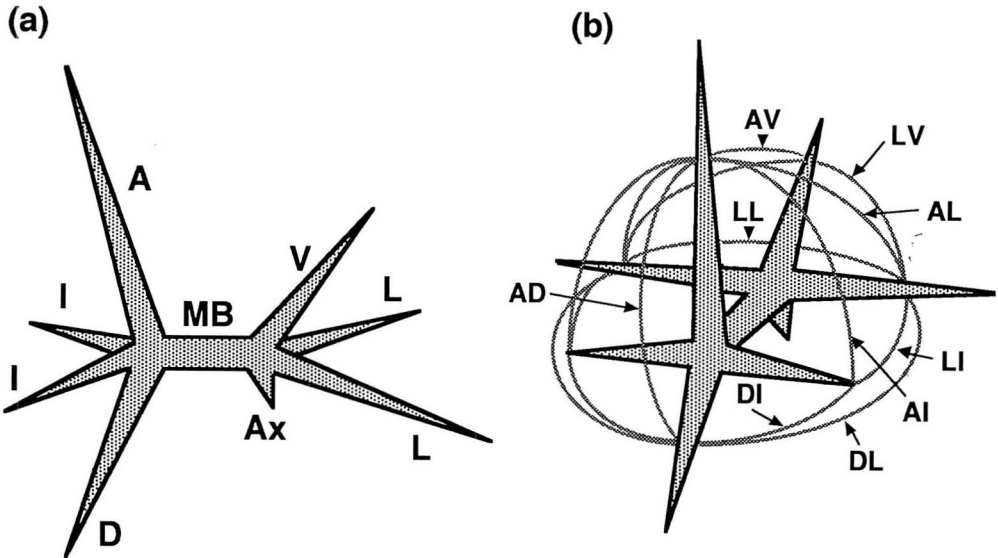


Figure 8. Schematic illustrations of internal spicule in nassellarian cephalis. (a): Lateral view. MB = median bar, A = apical ray (spine), D = dorsal ray (spine), L = primary lateral ray (spine), I = secondary lateral ray (spine), V = vertical ray (spine), Ax = axial spine. (b): Oblique dorsal view with arches connecting rays. For example, AV means an arch connecting A and V. Other arches are abbreviated in the same way.

species of the genera *Triassobipedis* Kozur, *Bulbocyrtium* Kozur and Mostler, *Eonapora* Kozur and Mostler and *Archaeosemantis pterostephanus* Dumitrica were also obtained from a few samples not treated in this study.

This assemblage is easily distinguished from the *T. deweveri* assemblage of Yao (1982) by the absence of *T. deweveri*, *Yeharaia eleaans* Nakaseko and Nishimura and so on. Co-occurring conodonts represent the *Neogondolella bulgarica* assemblage of Koike (1981). Thus it is clear that the age of this assemblage ranges at least from middle to late Anisian. In addition, the following facts can be pointed out: (1) Mizutani and Koike (1982) reported the occurrence of late Anisian radiolarians containing *T. deweveri* (described as *T. scalaris*) in bedded chert beds distributed in the Unuma area approximately 15 km east of Mt. Kinkazan. (2) The component species of this assemblage are similar to middle Anisian radiolarians from Samples F and G of Matsuda and Isozaki (1982). (3) The Tc assemblage is accompanied by a large amount of detached oertlispongoid spines. However, strikingly bent spines of *Oertlispongus inaequispinosus* Dumitrica, Kozur and Mostler, 1980, and *Falcispongus calcaneum* Dumitrica, 1982a, which are late Anisian to early Ladinian indexes according to Dumitrica (1982a), are never present. On the basis of these facts, it is concluded that the age of the Tc assemblage is middle Anisian and older than the *T. deweveri* assemblage.

Systematic Paleontology

Descriptive terminology of nassellarian cephalic elements is given in Figure 8. It is also adopted on some entactinarian species. Specimens described in this paper are deposited in the Department of Earth and Planetary Sciences, School of Science, Nagoya University (ESN).

Class Radiolaria
Order Nassellaria

Family *Plagiacanthidae* Hertwig, 1879,
emend. Petrushevskaya, 1971

Genus *Tetrarchiplagia* Dumitrica, 1982c
Type species.—*T. arboressens* Dumitrica, 1982c.

Tetrarchiplagia simplex Sugiyama, sp. nov.

Figures 9-1a, 1b

Description.—Eight spines arising from the ends of **MB**, constructing an extremely spicular form. **A**, **D** and two **L** straight, commonly with four spinules which originate from one level. Spinules conical, variable in length, always unbranched. **A** is the longest of the eight spines. **D** and two **L** nearly equal in shape. Thickness of these four spines either uniform or somewhat increasing to the level of spinules beyond which they rapidly taper. **V** straight, without spinules, distally tapering, much thinner than **A**, **D** and two **L**. The two **I** and **Ax** are present but very short. Arches completely absent.

Remarks.—This species is distinguished from previously known species of the genus by the character of spinules which are conical in shape and originate at one level.

Dimensions (in μm).—Based on 46 specimens. Length of **A**; 65-95. Length of **D**; 30-60. Length of **L**; 30-60. Length of **V**; 10-30.

Holotype.—ESN 146126 (Figures 9-1a, 1b) from KIN 38.

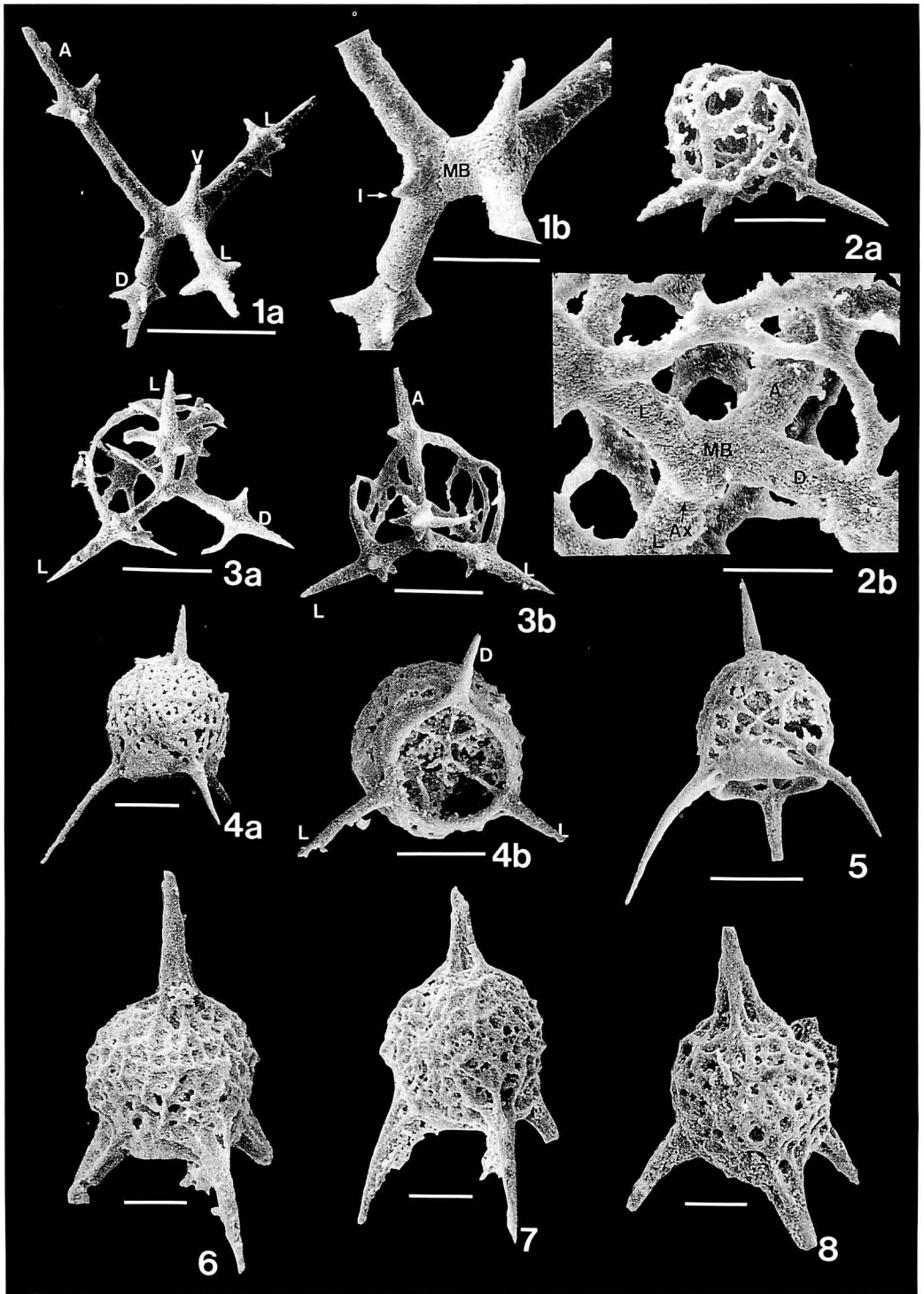
Occurrence.—KIN 29, 30, 33, 34, 36, 38, 40, 49, 51, 54, 56 and 108 (Pn assemblage) and KIN 65 (Hg assemblage).

Genus *Zamolxis* Dumitrica, 1982c
Type species.—*Z. corona* Dumitrica, 1982c.

Zamolxis dumitricai Sugiyama, sp. nov.

Figures 9-2a-3b

Description.—Six spines arising from the ends of **MB**. **A**, **D** and two **L** nearly equal in shape, possessing a circular cross section and



one verticil at the middle. Spines gradually increasing in thickness to the verticil and tapering beyond it. The verticil composed of four spinules of which the shorter ones are conical and the longer ones are curved inward. The longer spinules are partly or completely united with others radiating from other spines to form some arches. Secondary, delicate meshwork also developed between them. **V** rod-like, without spinules, shorter and thinner than **A**, **D** and two **L**. It is almost as thick as the arches. Two **I** completely missing. **Ax** short but distinct.

Remarks.—This species is distinguished from *Z. corona* and *Z. tardus* Dumitrica, 1982c, by possessing secondary meshwork connecting the arches and forming a definable cephalic wall. Further the former species differs from the latter two species in lacking a second verticil on each spine. Stratigraphic position of this species and *T. simplex* sp. nov. is the lowest among hitherto known plagiacanthids.

Dimensions (in μm).—Based on 23 specimens. Length of **A**; 45–90. Length of **D**; 45–90. Length of **L**; 45–90.

Holotype.—ESN 146129 (Figures 9-2a, 2b) from KIN 40.

Occurrence.—KIN 40 and 52 (Pn assemblage).

Etymology.—This species is named after Dr. Paulian Dumitrica, Romania, in honor of his great contribution to the study of radiolarians.

Family Poulpidae De Wever, 1981

Remarks.—This taxon was originally established as a subfamily of Pylentonemidae Deflandre, 1963, by De Wever (1981). However, Cheng (1986) revealed that *Pylentonema*

Deflandre, 1963, the type genus of Pylentonemidae, has a medullary shell, which is quite different feature from Mesozoic monosegmented nassellarians belonging to Poulpinae. According to his illustrations, archocyrtiids seem to have a similar internal skeletal structure to Poulpinae, but no occurrences of archocyrtiid populations are known from the Permian. Thus one can conclude that those Paleozoic and Mesozoic monosegmented nassellarians are homeomorphic forms. Takemura (1986) referred poulpins to the Cenozoic family Acanthodesmiidae Haeckel, 1862, also having a sagittal ring in the skeleton. In my opinion, however, it is much more suitable to raise the original Poulpinae to family rank since it is not known from the Upper Cretaceous.

Genus *Hozmadia* Dumitrica, Kozur and Mostler, 1980

Type species.—*H. reticulata* Dumitrica, Kozur and Mostler, 1980.

Hozmadia ozawai Sugiyama, sp. nov.

Figures 9-4a–5

Description.—Cephalis hemispherical to subhemispherical, with an apical spine and three feet. **MB** is situated approximately in the lower third of the cephalis, from the ends of which arise **A**, **D**, two **L**, two **I** and **V**. Cephalic wall commonly thin, fragile, with pores irregular in shape, size and arrangement, and with well expressed arches outside it. The wall is rather thick near the base which is circular in shape and rimmed by two **AL** and **LL**. The cephalis of immature or partly dissolved individuals defined only by

← **Figure 9.** **1a, 1b:** *Tetrarchplagia simplex* sp. nov., ESN 146126, holotype, KIN 38. **2a–3b:** *Zamolxis dumitricai* sp. nov. **2a:** ESN 146129, holotype, KIN 40. **A** is broken off. **2b:** Enlargement of **MB**, oblique basal view. **3a:** ESN 146127, paratype, KIN 40, oblique basal view. **3b:** Dorsal view. **4a–5:** *Hozmadia ozawai* sp. nov. **4a:** ESN 146112, holotype, KIN 40. **4b:** Basal view. **5a:** ESN 146113, paratype, KIN 50, ventral view. **6–8:** *Hozmadia gifuensis* sp. nov. **6:** ESN 146119, holotype, KIN 61. **7:** ESN 146117, paratype, KIN 61. **8:** ESN 146118, paratype, KIN 61. Scale bars: 1b and 2b=20 μm ; others=50 μm .

imperfect arches with loose, secondary meshwork. Apical spine aligned with **A**, rodlike, with circular cross section, acute in distal portion, and commonly long. Three feet extending from two **L** and **D**, connected with the collar edge, divergent approximately 45° downward below the horizontal, gently curved inward from the middle to distal part. They are also circular in cross section. The apical spine and feet sometimes bladed at the most proximal part. The two **I** and **V** connected with the cephalis above the collar edge.

Remarks.—This species is distinguished from previously known species of the genus by having rodlike apical spine and feet, and its fragile cephalic wall. The variation of the development of cephalic wall is, however, quite wide in a population from one sample.

Dimensions (in μm).—Based on 30 specimens. Height of cephalis; 60–100. Width of cephalis at the base; 60–90. Length of apical spine; 45–65. Length of foot; 60–95.

Holotype.—ESN 146112 (Figures 9-4a, 4b) from KIN 40.

Occurrence.—KIN 6, 20, 21, 29, 30, 32, 33, 35–40, 49–52, 54–57, 100, 108 and 109 (Pn assemblage).

Etymology.—This species is named in honor of Dr. Tomowo Ozawa of Nagoya University, whose help and continued encouragement have contributed to this study.

Hozmadia gifuensis Sugiyama, sp. nov.

Figures 9-6–8

Hozmadia (?) sp. A-Yao, 1982, pl. 1, fig. 15.

Saitoum (?) sp.-Yao *et al.*, 1980, pl. 1, fig. 7

(?) *Hozmadia* cf. *reticulata* Dumitrica, Kozur and Mostler-Bragin, 1991, p. 97, pl. 1, fig. 7

(?) *Hozmadia* (?) sp. -Matsuda and Isozaki, 1982, pl. 3, figs. 29, 30.

(?) *Hozmadia* sp. -Bragin *et al.*, 1988, pl. 2, fig. 2.

(?) *Poulpus* (?) sp. -Kido, 1982, pl. 2, fig. 9.

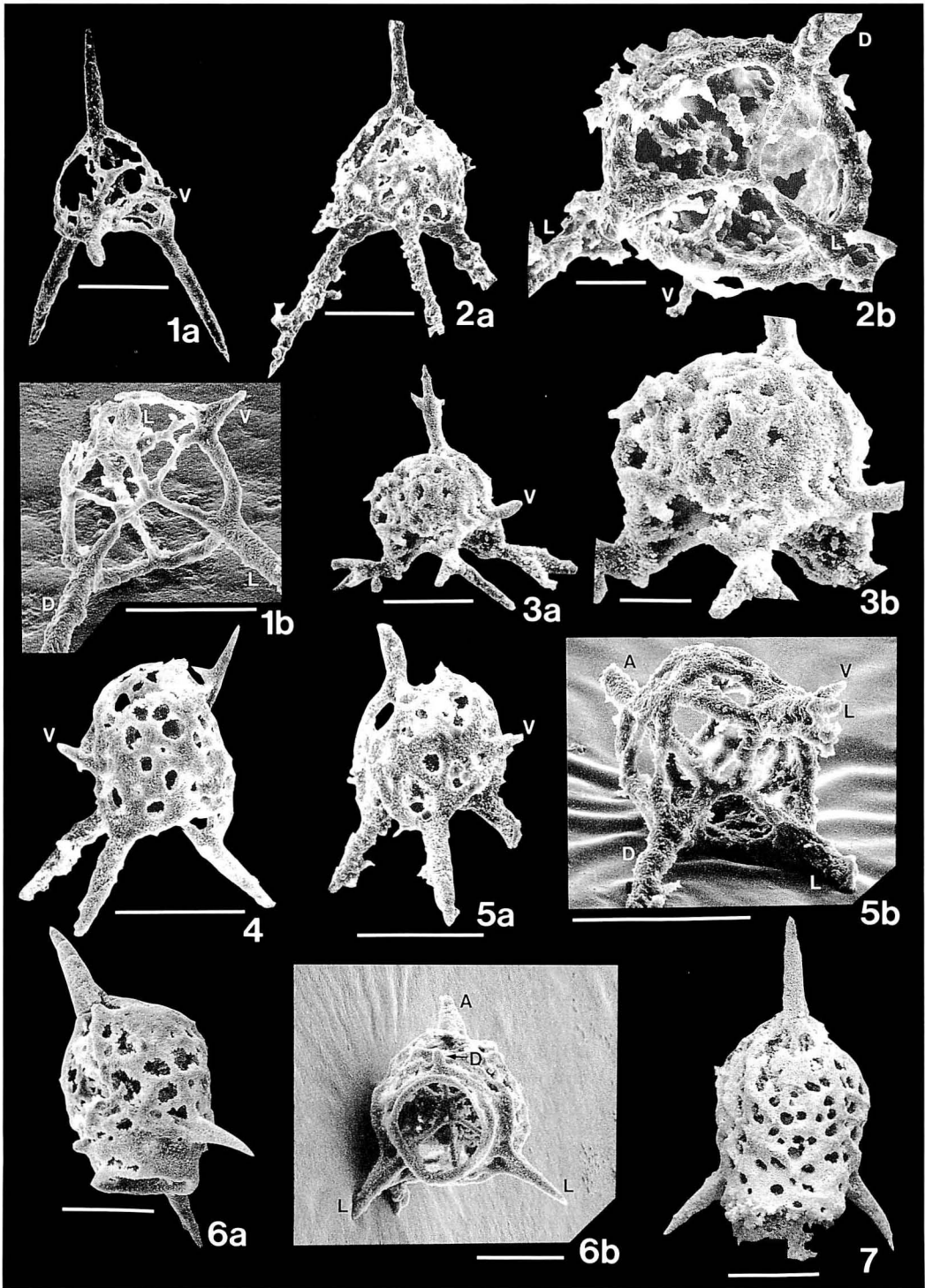
(?) *Poulpus* sp. A-Cheng, 1989, p. 148, pl. 5, fig. 10.

(?) *Nassellaria* I-Sato *et al.*, 1986, pl. 1, fig. 4.

Description.—Cephalis subhemispherical, usually constricted at the base, with an apical spine and three feet. Cephalic wall thick, rugged, pierced by a large number of circular to oval, sometimes irregularly shaped pores surrounded by polygonally shaped frames which bear small nodes at the junctions. On the cephalic surface arches are traceable. Collar edge, whose diameter is approximately half the equatorial portion, is marked by a circular to subtriangular thick peristome. Spicule construction as with the genus. Apical spine commonly stout, tapered, variable in length. Its proximal part is more or less bladed and middle and distal parts are rodlike. Feet divergent, directed approximately 45° downward below the horizontal; their proximal part solid and three-bladed; middle part bladed or non-bladed; and distal part circular in cross section, tapered, and more or less curved inward. The feet in contact or not with the base of cephalis. They may arise above the collar edge when their blades are weakly developed.

Remarks.—The present species is distinguished from *H. ozawai* sp. nov. by having solid cephalic wall and prominent blades on the proximal part of the apical spine and feet. Immature or dissolved individuals of this species are, however, somewhat similar to the latter species. They can be distinguished by the position of feet, namely many specimens of *H. gifuensis* sp. nov. have them above the base of cephalis in such cases. This species differs from *H. rotunda* (Nakaseko and Nishimura, 1979) in lacking blades on the distal part of the apical spine. Moreover, the apical spine of *H. gifuensis* sp. nov. is less

→ **Figure 10.** **1a-2b:** *Poulpus nishimurae* sp. nov. **1a:** ESN 146121, holotype, KIN 38. **1b:** Basal view. **2a:** ESN 146123, paratype, KIN 56. **2b:** Basal view. **3a, 3b:** *Poulpus nakasekoi* sp. nov., ESN 146124, holotype, KIN 65. **4-5b:** *Tripedocorbis* sp. A. **4:** ESN 146132, KIN 38. **5a:** ESN 146130, KIN 38. **5b:** Basal view. **6a-7:** *Triassobipedis* (?) *aetoides* sp. nov. **6a:** ESN 146148, holotype, KIN 50, lateral view. **6b:** Basal view. **7:** ESN 146147, paratype, KIN 49, dorsal view.



developed than that of the latter species. One can regard this species as an intermediate form between *H. ozawai* and *H. rotunda*, and all of them possibly represent one and the same species through time. As it is difficult to prove such a fact for the present, detailed studies are necessary to solve the problem. This species differs from *H. reticulata* in having a rather slender apical spine and three-bladed rather than four-bladed feet.

Dimensions (in μm).—Based on 35 specimens. Height of cephalis; 100–140. Width of cephalis at the equatorial portion; 105–150. Width of cephalis at the base; 70–100. Length of apical spine; 70–130. Length of foot; 75–135.

Holotype.—ESN 146119 (Figure 9–6) from KIN 61.

Occurrence.—KIN 58–62, 64–68 (Hg assemblage) and KIN 44, 69, 71 and 73 (Tc assemblage).

Etymology.—The name is derived from Gifu City, type locality.

Genus *Poulpus* De Wever, 1979

Type species.—*P. piabyx* De Wever, 1979.

Poulpus nakasekoi Sugiyama, sp. nov.

Figures 10–3a, 3b

Description.—Cephalis subhemispherical, relatively small, with an apical spine and three feet. Cephalic wall perforate, more or less rough, with small nodes and arches well marked. Apical spine thin, rodlike, having one verticil of three conical spinules at the middle or distal part. **MB** lying in the base of cephalis. **D**, two **L** and two **I** connected with the collar edge. Three feet arising from

two **L** and **D**, nearly straight, diverging approximately 30° downward from the horizontal, not bladed, three-pronged distally. **V** extending to the collar edge, and prolonged into a conical spine.

Remarks.—This species is similar to *P. hirsutus* De Wever, 1982, in the general shape. The former, however, differs from the latter in lacking bladed feet and having branches even on the apical spine.

Dimensions (in μm).—Based on 18 specimens. Height of cephalis; 40–70. Width of cephalis at the base; 65–90. Length of apical spine; 45–65. Length of vertical spine; up to 35. Length of foot; 35–65.

Holotype.—ESN 146124 (Figures 10–3a, 3b) from KIN 65.

Occurrence.—KIN 65 (Hg assemblage) and KIN 42, 44, 45, 65 and 69 (Tc assemblage).

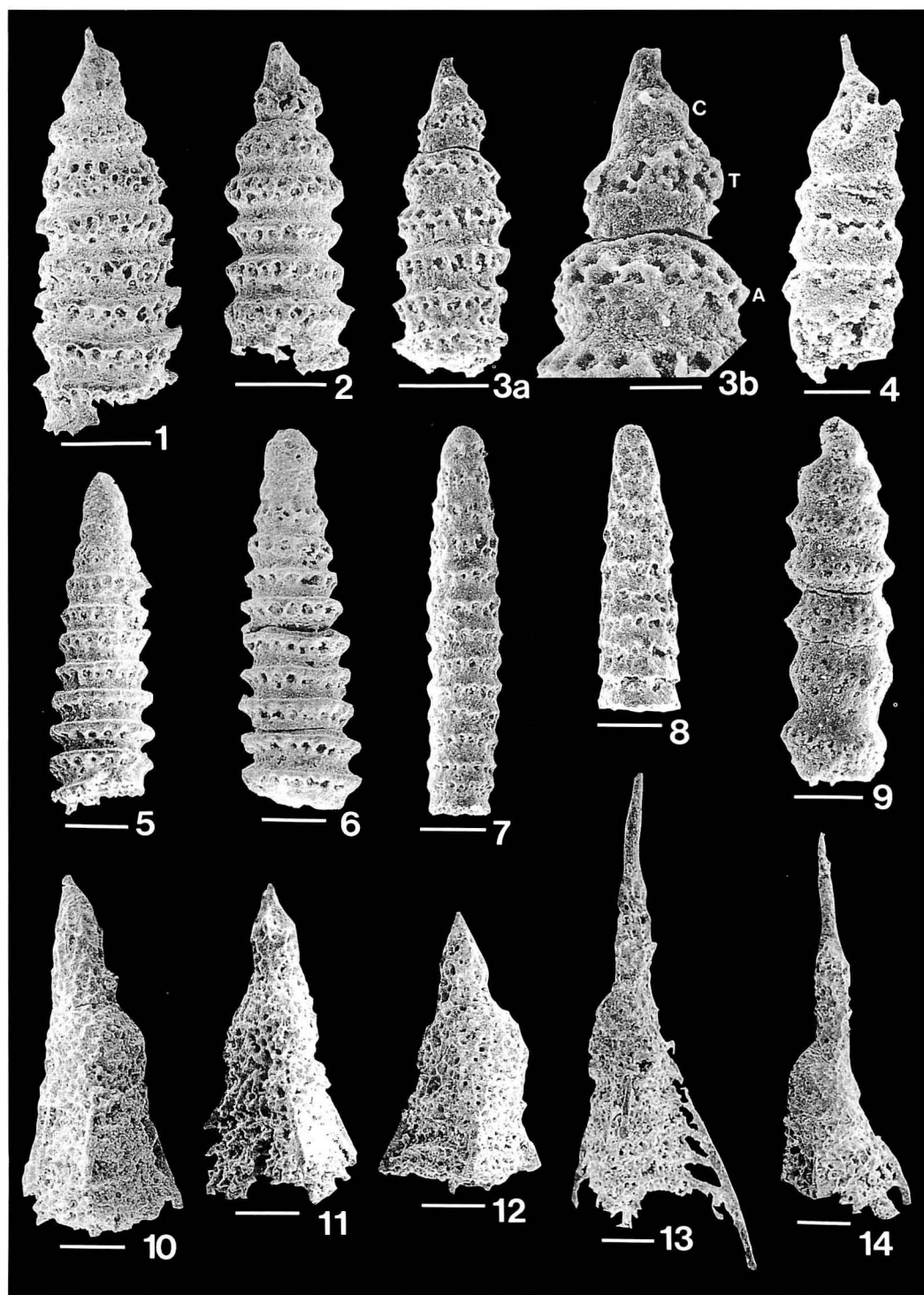
Etymology.—This species is named in honor of Prof. Kojiro Nakaseko, the leading person of radiolarian study in Japan.

Poulpus nishimurae Sugiyama, sp. nov.

Figures 10–1a–2b

Description.—Cephalis subhemispherical, with an apical spine and three feet. Cephalic wall incomplete, generally defined by arches with loose, secondary meshwork. **MB** lying in the base of cephalis. Apical spine rodlike, with pointed end, variable in length, extending from **A**. **D**, two **L** and two **I** connected with the collar edge. Three feet long, gently curved inward, diverging approximately 45° to 60° downward from the horizontal, not bladed, with pointed ends, arising from the two **L** and **D**. **V** tied to the base of cephalis, prolonged or not into a conical

→ **Figure 11.** 1–3b: *Triassocampe myterocorys* sp. nov. 1: ESN 146133, holotype, KIN 45. 2: ESN 146287, paratype, KIN 45. 3a: ESN 146136, paratype, KIN 45. 3b: Enlargement of the proximal part. C=cephalis, T=thorax, A=abdomen. 4, 9: *Triassocampe* (?) sp. A. 4: ESN 146144, KIN 65. 9: ESN 146145, KIN 68. 5, 6: *Triassocampe coronata* Bragin. 5: ESN 146137, KIN 45. 6: ESN 146138, KIN 45. 7, 8: *Triassocampe* sp. aff. *T. diordinis* Bragin. 7: ESN 146142, KIN 45. 8: ESN 146141, KIN 45. 10–12: *Spongosilicarmiger scabiturritus* sp. nov. 10: ESN 146162, holotype, KIN 45. 11: ESN 146161, paratype, KIN 45. 12: ESN 146163, paratype, KIN 50. 13, 14: *Spongosilicarmiger mostleri* sp. nov. 13: ESN 146160, holotype, KIN 45. 14: ESN 146159, paratype, KIN 45. Scale bars: 3b=20 μm ; others=50 μm .



spine.

Remarks.—This species is easily distinguished from the previously known species of the genus by having rodlike apical spine and feet, and incomplete cephalic wall.

Dimensions (in μm).—Based on 22 specimens. Height of cephalis; 50–75. Width of cephalis at the base; 65–85. Length of apical spine; 45–80. Length of vertical spine; up to 30. Length of foot; 50–120.

Holotype.—ESN 146121 (Figures 10-1a, 1b) from KIN 38.

Occurrence.—KIN 34, 37, 38 and 40 (Pn assemblage).

Etymology.—This species is named after Dr. Akiko Nishimura in honor of her great contribution to the study of Mesozoic and Cenozoic radiolarians.

Family Ruesticyrtiidae Kozur
and Mostler, 1979

Genus *Triassocampe* Dumitrica, Kozur and Mostler, 1980

Type species.—*T. scalaris* Dumitrica, Kozur and Mostler, 1980 (a junior objective synonym of *Dictyomitrella deweveri* Nakaseko and Nishimura, 1979).

Triassocampe myterocorys Sugiyama, sp. nov.

Figures 11-1–3b

(?) *Triassocampe* (?) sp. G-Yao, 1982, pl. 1, fig. 7.
-Matsuda and Isozaki, 1982, pl. 3, figs. 1–3, 20–24.-Arakawa, 1986, pl. 5, figs. 1–3.

Description.—Cephalis very small, imperforate, conical to hemispherical, having an apical spine which is conical and often obliquely directed. Collar stricture is commonly visible, but far shallower than following ones. Thorax wider than cephalis, hemispherical, nodulated, usually pierced by small pores irregularly arranged. Abdomen and the fourth segment barrel-shaped, wider than thorax, with many pores scattered or aligned in transverse rows, and usually lacking the development of circumferential ridge.

Length of abdomen variable, either longer or shorter than the fourth segment. Width of abdomen more or less narrow than the fourth segment. The fifth segment has morphologic similarity either to the fourth or sixth one. It sometimes has fairly intermediate features between them. The sixth and all the subsequent segments subtrapezoidal in outline, with circumferential ridges just below constrictions. The circumferential ridges become prominent distally. Pores variable from circular to polygonal in shape, usually aligned in one or two transverse rows below each circumferential ridge. They are sometimes arranged without any regularity.

Remarks.—This species resembles *T. multinerforata* (Kozur, 1984) in the morphology of thorax, abdomen and the fourth segment. The former is, however, distinguished from the latter by lacking a stout, bladed apical spine. Morphologic variety of this species is very wide.

Dimensions (in μm).—Based on 47 specimens. Length of apical spine; up to 25. Height of cephalis and thorax; 30–45. Width of thorax; 30–45. Height of abdomen; 15–30. Width of abdomen; 40–60. Height of fourth segment; 25–35. Width of fourth segment; 55–75. Height of fifth segment; 20–35. Width of fifth segment; 60–80.

Holotype.—ESN 146133 (Figure 11-1) from KIN 45.

Occurrence.—KIN 41, 42, 44–46, 69, 70 and 73 (Tc assemblage).

Triassocampe coronata Bragin

Figures 11-5, 6

(?) *Dictyomitrella* sp. A-De Wever in De Wever *et al.*, 1979, p. 90, pl. 5, figs. 12, 16.

Triassocampe (?) sp. aff. *T.* sp. A of Yao (1982) -Matsuda and Isozaki, 1982, pl. 3, figs. 4–9.-Arakawa, pl. 5, figs. 5–7.

Triassocampe sp. A-Takashima and Koike, 1982, pl. 1, figs. 3, 4.-Kojima and Mizutani, 1987, p. 265, fig. 3; 1.

Triassocampe deweveri (Nakaseko and Nishimura,

1979)-Nishizono *et al.*, 1982, pl. 3, fig. 13.(?)

Triassocampe deweveri-Kishida and Sugano, 1982, pl. 1, fig. 10.

Triassocampe coronata Bragin, 1991, p. 99, pl. 1, fig. 15.

Description.—Cephalis dome-shaped, imperforate, larger than that of *T. myterocorys* sp. nov. It sometimes bears a weak, wart-like apical spine. Collar stricture almost indistinct outside. Thorax barrel-shaped in outline, either imperforate or pierced by scattered small pores, more or less wider but shorter than cephalis. Lumbar stricture slightly visible. Abdomen barrel-shaped to subtrapezoidal in outline, wider than thorax, nodose, pierced by scattered or somewhat arranged pores, without circumferential ridge. Each postabdominal segment subtrapezoidal in outline, with imperforate stricture, nearly uniform in length and width, having well-developed circumferential ridge in the upper portion. Those circumferential ridges become prominent in the distal segments. A single row of circular pores situated just beneath each circumferential ridge.

Remarks.—This species is distinguished from *T. myterocorys* sp. nov. by the characters of cephalis and pore arrangement. It resembles *T. deweveri* in the cephalic feature but differs from the latter in having only a single row of pores beneath each circumferential ridge.

Dimensions (in μm).—Based on 35 specimens. Length of apical spine; up to 5. Height of cephalis, thorax and abdomen; 65–85. Width of abdomen; 55–65. Height of fourth segment; 20–35. Width of fourth segment; 55–75. Height of fifth segment; 20–35. Width of fifth segment; 55–85.

Occurrence.—KIN 41–46, 69–73 (Tc assemblage).

Triassocampe sp. aff. *T. diordinis* Bragin

Figures 11–7, 8

aff. *Triassocampe* (?) sp. aff. *T.* sp. H of Yao (1982)-Matsuda and Isozaki, 1982, pl. 3, figs. 12–15, 17–

19.

aff. *Triassocampe diordinis* Bragin, 1991, pl. 1, fig. 8; pl. 9, fig. 4.

Remarks.—This species is typically characterized by having a single row of pores just beneath the poorly developed circumferential ridges. However, the features is so variable that the species is possibly conspecific with *T. diordinis*.

Occurrence.—KIN 45 (Tc assemblage).

Triassocampe (?) sp. A

Figures 11–4, 9

Remarks.—The test is formed of many, usually more than five, barrel-like segments and a short apical spine may be present on the cephalis. The occurrence is relatively common in the Hg assemblage, but completely preserved specimens have not been obtained yet and the details of pore features are at the present time not well understood. The general shape is somewhat resembles *T. myterocorys* sp. nov. but differs from the latter in lacking prominent circumferential ridges.

Occurrence.—KIN 60, 62, 64–66 and 68 (Hg assemblage).

Family Silicarmigeridae Kozur
and Mostler, 1980

Genus *Spongosilicarmiger* Kozur, 1984

Type species.—*S. italicus* Kozur, 1984.

Spongosilicarmiger mostleri Sugiyama, sp. nov.

Figures 11–13, 14

Description.—Cephalis subhemispherical, imperforate, with rugged surface, sometimes pierced by very small pores irregularly scattered. Apical spine composed of three parts; distal part rodlike, tapering, nearly straight; middle part porous, formed of four or more longitudinal ridges connected by transverse bars; proximal part robust, imperforate, rugged, probably hollow. Three feet long, thin, rodlike, arising from the collar stricture

which is usually hidden by spongy fabric or granules, and connected with the transverse ridges on thorax and postthoracic segments through several thin bars. The postthoracic segments long, nearly cylindrical, spongy, with numerous small pores.

Remarks.—This species is distinguished from *S. italicus* by its long and slender apical spine. The middle of the apical spine of the former species is homologous with that of the latter which is characterized by marked expanding.

Dimensions (in μm).—Based on 17 specimens. Length of apical spine; 180–230. Thickness of apical spine in distal part: 15–20. Thickness of apical spine in proximal part; 25–35. Height of cephalis; 50–80. Maximum width of cephalis; 60–80. Length of foot; 90–270.

Holotype.—ESN 146160 (Figure 11–13) from KIN 45.

Occurrence.—KIN 44, 45 and 69 (Tc assemblage).

Etymology.—This species is named after Dr. Helfried Mostler, Austria, in honor of his great contribution to Paleozoic and Mesozoic micropaleontology.

Snongosilicarmiger scabiturritus Sugiyama
sp. nov.

Figures 11–10–12

Description.—Cephalis subhemispherical, rugged, pierced by numerous small pores, and having a robust apical spine. Apical spine usually subvertical; proximal to middle part porous, rugged, probably hollow; distal part conical, rapidly tapered to a point. Three feet extending from the base of cephalis may be prolongations of **D** and two **L**. Thorax and postthoracic segments hemmed by feet, rugged, porous, gradually increasing in the width distally, and often bearing transverse ridges.

Remarks.—This species resembles *S. nakasekoi* Yeh, 1990, from which it differs in having perforated and rugged cephalic wall.

Dimensions (in μm).—Based on 31 specimens. Length of apical spine; 60–120. Height of cephalis; 60–90. Maximum width of cephalis; 65–90. Length of foot; 35–100.

Holotype.—ESN 146162 (Figure 11–10) from KIN 45.

Occurrence.—KIN 41, 44, 45, 69, 70 and 72 (Tc assemblage).

Family Tripedurnulidae Dumitrica, 1991

Genus *Tripedocorbis* Dumitrica, 1991

Type species.—*T. ramulispinus* Dumitrica, 1991.

Tripedocorbis sp. A

Figures 10–4–5b

Description.—Cephalis subhemispherical, with an apical spine, three feet and a short vertical spine. Cephalic wall fragile, pierced by circular to subcircular pores which are randomly arranged. Density of the pores variable among specimens. The base of the cephalis not in a plane, rimmed by two **D1**, two **L1**, two **L2**. **LL** missing. Apical spine needlelike, nearly straight, arising from **A**, and obliquely directed. **V** directing approximately 45° upward from the horizontal, having a point contact with the base of the cephalis, and forming an acute spine beyond it. Three feet extending from **D** and two **L**, typically rodlike, straight, more or less tapering distally, and directing approximately 45° or more downward from the horizontal. In some specimens proximal part of each foot is slightly bladed, then the blades are connected with others on neighboring foot by arches.

Remarks.—Although Dumitrica (1991) defined the genus as one not having three-bladed feet, the details of the proximal part of the feet were often unobservable in my materials due to the poor preservation. Thus some individuals having relatively thick feet possibly belong to the genus *Baratuna* Kozur and Mostler, 1981. This species resembles *T. blomei* Dumitrica from which it differs in

lacking thorns on the feet.

Dimension (in μm).—Based on 25 specimens. Height of cephalis; 45–70. Width of cephalis at the base; 40–60. Length of apical spine; 20–45. Length of foot; 10–20

Occurrence.—KIN 2, 6, 14, 21, 29, 33–36, 39, 40, 47–50, 52–54, 56, 97–100 and 108–111 (Pn assemblage) and KIN 58 (Hg assemblage).

Incerta Family

Genus *Hinedorcus* Dumitrica, Kozur and Mostler, 1980

Type species.—*H. alatus* Dumitrica, Kozur and Mostler, 1980.

Hinedorcus holdsworthi Sugiyama, sp. nov.

Figures 12-5a, 5b

Description.—Cephalis small, subhemispherical to hemispherical, poreless or pierced by a small number of nearly circular, small pores, having an apical spine and three feet, with or without a vertical spine. Apical spine well developed, rodlike to conical, tapered to a point. It is usually obliquely directed, nearly straight or gently curved upward in proximal part. Vertical spine is very short, generally vestigial, and surrounded by small pores at the base, when it is present. Three feet directed downward, rodlike, probably extending from **D** and the two **L**, arising from the collar stricture, and amalgamated with thoracic wall at the proximal to middle part. Thorax long, barrel-shaped, with scattered, small, circular to irregularly shaped pores.

Remarks.—The skeletal structure could not be confirmed at this time. This species differs from the type species in its rodlike apical spine and feet.

Dimensions (in μm).—Based on 15 specimens. Length of apical spine; 25–45. Height of cephalis; 35–45. Maximum width of cephalis; 30–50. Length of foot; 40–80.

Holotype.—ESN 146158 (Figures 12-5a,

5b) from KIN 37.

Occurrence.—KIN 34, 37, 40 and 56 (Pn assemblage) and KIN 58, 60 and 65 (Hg assemblage).

Etymology.—This species is named after Dr. B.K. Holdsworth, University of Keele, England, in honor of his great contribution to the study of Paleozoic radiolarians.

Genus *Nofrema* Dumitrica, Kozur and Mostler, 1980

Type species.—*N. trispinosa* Dumitrica, Kozur and Mostler, 1980.

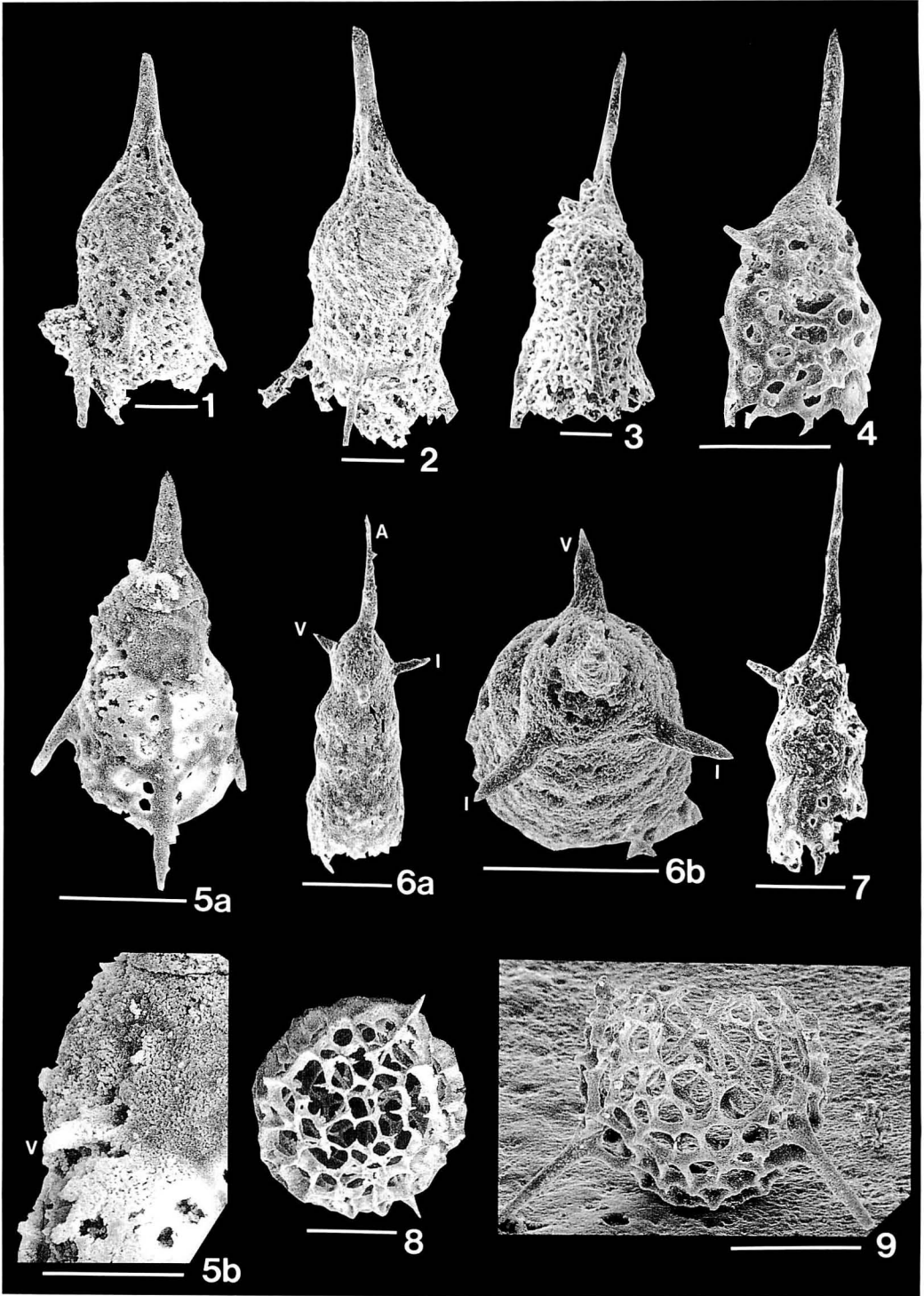
Nofrema (?) *gigantoceras* Sugiyama, sp. nov.

Figures 12-1–3

Description.—Cephalis large, porous, subhemispherical, with a stout, long apical spine. Cephalic wall rugged, pierced by many small pores. Arches sometimes faintly visible on it. Apical spine gently tapering distally, directed more or less obliquely, consisting of bladed proximal part and rodlike middle to distal one. Thorax cylindrical, more or less increasing distally in width. Maximum width of thorax generally less than that of cephalis. Thoracic wall similar to cephalic one. Collar stricture marked externally by a gentle change in contour, from which prolongations of **D** and two **L** extend downward. They hem the thoracic wall proximally, and gradually detach from the wall to form three, rodlike feet.

Remarks.—The present species is distinguished from *N. trispinosa* by its much expanded cephalis and by lacking constrictions on the thorax. This species differs from hitherto known *Spongosilicarmiger* species in its much larger cephalis. It is tentatively assigned to *Nofrema* but may be an ancestral form of *Spongosilicarmiger* or independent of both the genera.

Dimensions (in μm).—Based on 45 specimens. Height of cephalis; 80–115. Maximum width of cephalis; 95–115. Height of thorax; 75–120. Maximum width of tho-



rax; 50-70. Length of foot; 50-140.

Holotype.—ESN 146156 (Figure 12-1) from KIN 61.

Occurrence.—KIN 60-62, 64 and 65 (*Hozmadia gifuensis* assemblage).

Genus *Triassobipedis* Kozur, 1984

Type species.—*T. balatonica* Kozur, 1984.

Triassobipedis (?) *aetoides* Sugiyama, sp. nov.

Figures 10-6a-7

Description.—Cephalis elongated dome-shaped, swollen in the upper half, and rather tight in the lower half. Internal spicule composed of **MB**, **A**, **D**, two **L**, two **I** and **V**. **Ax** missing. **MB** situated approximately in the lower third of cephalis. The base of cephalis circular in shape. Cephalic wall with circular to oval, sometimes irregularly shaped pores disposed at random. They are usually much denser in the upper half of the cephalis, whereas the peristome of cephalis is nearly imperforate. Arches visible on the wall. Apical spine extending from **A** is obliquely directed but always situated in the sagittal plane. It is acute, circular in cross section, sometimes bladed at the proximal part. Those blades corresponding to the terminals of arches. The two **L** extend outside the wall into two well-developed feet located much above the cephalic base. They are rodlike, acute, circular in cross section, directed obliquely downward, and situated at an angle of 120-150° to each other. With or without the third foot which is vestigial and prolonged from **D**.

Remarks.—This species clearly differs from *T. balatonica* in its porous cephalic wall and rather slender feet. Moreover, the feet of this species do not contact the base of the cephalis

as with the latter species. It is probably a transitional form from *Hozmadia* to typical *Triassobipedis* taking account of its general shape and the presence of vestigial third foot extending from **D** on some individuals. The precise generic assignment thus remains questionable.

Dimensions (in μm).—Based on 26 specimens. Height of cephalis; 90-125. Maximum width of cephalis; 75-95. Width of cephalis at the base; 30-43. Length of apical spine; 50-75. Length of foot arising from **L**; 35-60.

Holotype.—ESN 146148 (Figures 10-6a-6c) from KIN 50.

Occurrence.—KIN 37, 38, 40, 49 and 51 (Pn assemblage).

Genus *Zevius* Sugiyama, gen. nov.

Etymology.—The name is formed by arbitrary combination of letters, masculine gender.

Including species.—*Z. yaoi* Sugiyama sp. nov. (type species) and *Z. perarmatus* Sugiyama sp. nov.

Diagnosis.—Test commonly composed of more than two segments separated by shallow constrictions. Distinct internal partition between segments absent. Cephalis commonly poreless, sometimes pierced by scattered small pores. Internal spicule has not been observed yet, but external two spines which extend upward from the cephalis probably correspond to apical and vertical ones, respectively. Apical spine always well-developed, more or less obliquely directed especially in proximal part. Vertical spine short, thin, sometimes vestigial or missing. Thorax and the subsequent segments wider than cephalis, having scattered pores, without circumferential ridges. With or without

← **Figure 12.** 1-3: *Nofrema* (?) *gigantoceras* sp. nov. 1: ESN 146156, holotype, KIN 60. 2: ESN 146288, paratype, KIN 60. 3: ESN 146157, paratype, KIN 61. 4, 7: *Zevius yaoi* gen. et sp. nov. 4: ESN 146152, holotype, KIN 38. 7: ESN 146153, paratype, KIN 38. 5a, 5b: *Hinedorcus holdsworthi* sp. nov., ESN 146158, holotype, KIN 38. 6a, 6b: *Zevius perarmatus* gen. et sp. nov., ESN 146155, holotype, KIN 37. 8, 9: *Entactinia morii* sp. nov. 8: ESN 146165, holotype, KIN 49. 9: ESN 146166, paratype, KIN 49. Scale bars: 5b = 20 μm ; others = 50 μm .

other spines near the collar stricture.

Remarks.—This genus is distinguished from *Triassocampe* by having large apical spine and complete lack of deep constrictions and circumferential ridge on segments. The suprageneric assignment is not known yet.

Zevius yaoi Sugiyama, sp. nov.

Figures 12-4, 7

Description.—Cephalis small, subhemispherical to hemispherical, poreless or pierced by a small number of nearly circular small pores, with an apical spine, with or without a vertical spine, and without other spines. Apical spine rodlike, usually obliquely directed at the proximal part, straight or gently curved upward in the middle part, and terminated in a point. Vertical spine rodlike, directed obliquely upward, much thinner and shorter than apical one, sometimes vestigial or missing. Even if it is invisible outside, the intersecting point of corresponding ray to the cephalic wall can be inferred in most cases by a swell on the cephalis. Thorax and the subsequent segments usually barrel-shaped, always wider than cephalis, with many scattered pores of various size.

Remarks.—This species has a certain external morphology in common with *Goestlingella illyrica* Kozur, 1984. The former is, however, easily distinguished from the latter by lacking funnel-like abdomen. It also resembles *Stichomitra* (?) *triassica* Dumitrica, Kozur and Mostler, 1980, but differs from the latter in having much larger thorax. Because the internal spicule of this species has not been observed yet, further comparisons are difficult to make at present.

Dimensions (in μm).—Based on 40 specimens. Length of apical spine; 30-120. Length of vertical spine; up to 30. Height of cephalis; 25-40. Maximum width of cephalis; 35-50. Height of thorax; 30-50. Maximum width of thorax; 50-70.

Holotype.—ESN 146152 (Figure 12-4) from KIN 38.

Occurrence.—KIN 2, 34, 35, 37-40, 49, 54, 56, 100, 108 and 109 (Pn assemblage) and KIN 58, 61 and 65 (Hg assemblage).

Etymology.—This species is named after Dr. Akira Yao of Osaka City University in honor of his great contribution to the study of Mesozoic radiolarians.

Zevius perarmatus Sugiyama, sp. nov.

Figures 12-6a, 6b

Description.—Cephalis subhemispherical, nearly imperforate, with an apical, a vertical and two lateral spines. Apical spine rodlike, pointed, obliquely directed in the proximal part, straight or gently bent upward in the middle part. Vertical spine conical, directed obliquely upward. Two lateral spines arising from just above the collar stricture are also conical and very similar to vertical one. Judging from the relative positions to apical and vertical spines, they are probably prolongations of two **I**. Thorax and postthoracic segments barrel-shaped, gradually increasing in width distally, pierced by circular pores. Pores randomly arranged, increasing in number and size distally.

Remarks.—In my material, there is only one completely preserved specimen (holotype), on which the above description is mainly based. This species is easily distinguished from *Z. yaoi* sp. nov. by possessing two lateral spines. It probably has the same spicule construction as *Anisicyrtis* sp. A described by Goričan and Buser (1988/1989), which also has four spines extending from **A**, **V** and two **I**. They seem to be closely related to one another. This species differs from *Triassocampe hungariaca* (Kozur, 1984) in having a vertical spine, and rather short lateral spines. Moreover, lateral spines of the latter species are prolongations of the two **L**, according to the original description by Kozur (1984).

Dimensions (in μm).—Based on one specimen (holotype). Length of apical spine; 65. Length of vertical spine; 25. Length of lat-

eral spine; 30. Height of cephalis; 40. Maximum width of cephalis; 40. Height of thorax; 25. Maximum width of thorax; 50.

Holotype.—ESN 146155 (Figures 12-6a, 6b) from KIN 37.

Occurrence.—KIN 37, 38, 40 and 49 (Pn assemblage) and KIN 58 (Hg assemblage).

Order Entactinaria

Remarks.—The order Entactinaria, generally characterized by possessing an internal spicule and spherical shell, was proposed by Kozur and Mostler (1982). However, many investigators have not accepted their proposal yet and have included this type of radiolarian in the spumellarians. It is, however, certain that they are phylogenetically much closer to nassellarians than typical spumellarians, and should be separated from the latter, although separation at the order rank still remains debatable.

Family Entactiniidae Riedel, 1967a

Genus *Entactinia* Foreman, 1963

Type species.—*E. herculea* Foreman, 1963.

Entactinia morii Sugiyama, sp. nov.

Figures 12-8, 9

Description.—Shell single, spherical, latticed, with relatively large, subcircular to polygonal pores of irregular size. Lattice bars usually oval in cross section, bearing small nodes at junctions. Immature individuals(?) have edged bars and the lattice work is more or less imperfect. **MB** is eccentrically situated in the shell, with three rays on each end. The spicule system shows perfect tri-radial symmetry when one views along **MB**. The rays may or may not be prolonged into rodlike spines. They are variable in length, thicker than corresponding rays.

Remarks.—This species has a looser lattice shell and simple spines compared with all Permian species.

Dimensions (in μm).—Based on 23 speci-

mens. Diameter of shell; 110-160. Length of spine; up to 90.

Holotype.—ESN 146165 (Figure 12-8) from KIN 49.

Occurrence.—KIN 40, 49, 50 and 56 (Pn assemblage).

Etymology.—This species is named in honor of Dr. Shinobu Mori of Nagoya University, whose help and continued encouragement have contributed to this study.

Family Eptingiidae Dumitrica, 1978a

Remarks.—The suprafamily assignment is problematic because it has both entactinarian and nassellarian features. I tentatively include it in Entactinaria in this study although the descriptive terminology of the spicule system follows that of nassellarians. Dumitrica (1978a) defined Eptingiidae as a family possessing a sagittal ring and three spines prolonged from **A** and two **L**. In this case a problem arises with respect to the family assignment of *Tetrarhopalus* gen. nov., because it has four spines rather than three. Except for this feature, however, it has some morphology in common especially with *Cryptostephanidium* Dumitrica, 1978a, and they must be closely related. In this study, therefore, the original diagnosis of this family is tentatively enlarged to include *Tetrarhopalus* gen. nov.

Genus *Cryptostephanidium* Dumitrica, 1978a

Type species.—*C. cornigerum* Dumitrica, 1978a.

Cryptostephanidium longispinosum (Sashida)

Figures 13-1, 2

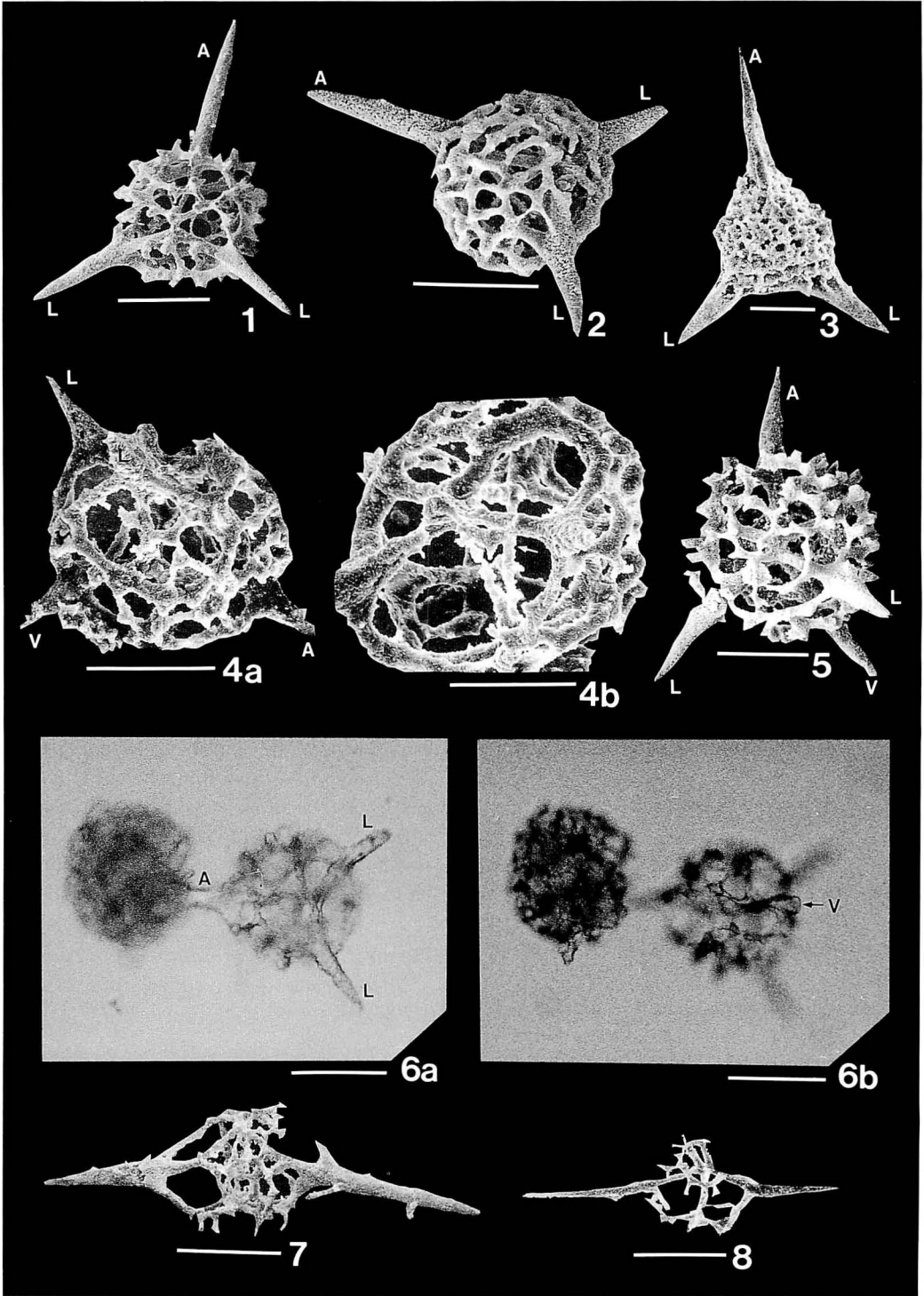
Tripocyclina janonica Nakaseko and Nishimura, 1979—Blome *et al.*, 1986, pl. 8.3, fig. 18.

Cryptostephanidium sp. A—Cheng, 1989, p. 148, pl. 6, fig. 3.

Cryptostephanidium sp. D—Cheng, 1989, p. 148, pl. 7, fig. 5.

Cryptostephanidium sp. E—Cheng, 1989, p. 148, pl. 7, fig. 6.

Cryptostephanidium (?) sp. B—Cheng, 1989, p. 148, pl.



6, fig. 4.

Cryptostephanidium (?) sp. C-Cheng, 1989, p. 148, pl. 6, fig. 11.

Spongostephanidium longispinosum Sashida, 1991, p. 694, figs. 7-1-8.

Description.—Shell subspherical, more or less compressed, latticed, with small nodes at the junctions of bars which form angular pore frame, and with three spines arising from **A** and two **L**. Lattice bars circular to oval in cross section. They are thin in immature individuals (?) and then often form rather incomplete and nodular shell. **D**, two **I**, **V** and **Ax** connected with the shell wall. Spines are acute, rodlike to conical, one of which extending from **A** is somewhat longer than the other two. Existence of sagittal ring presently not confirmed.

Remarks.—Sashida (1991) assigned this species to *Spongostephanidium* Dumitrica, 1978a. However, I have confirmed the presence of **D** which is a diagnostic feature of *Cryptostephanidium*. It is notable that specimens with free sagittal ring have not been found so far. It is at present difficult to decide whether the absence of sagittal ring is original or due to extracting procedure by HF method.

Dimensions (in μm).—Based on 19 specimens. Maximum diameter of shell; 65-100. Length of spine extending from **A**; 45-100. Length of spine extending from **L**; 30-65.

Occurrence.—KIN 29, 30, 32-40, 47-56, 98-100 and 108-111 (Pn assemblage) and KIN 58, 60-62, 64-67 (Hg assemblage).

Cryptostephanidium sp. cf. *C. verrucosum*
Dumitrica, 1978a

Figures 13-3

Remarks.—This species is characterized by its rough shell wall and proximally bladed spines, and is similar to *C. verrucosum* in the general shape. However, it differs from the latter species in having unequal spines of which one arising from **A** is relatively longer.

Occurrence.—KIN 58-61, 65 and 68 (Hg assemblage).

Genus *Tetrarhopalus* Sugiyama, gen. nov.

Etymology.—From the Greek *tetra*, four, and *rhopalon*, stick, masculine gender.

Type species.—*T. itoigawai* Sugiyama sp. nov. (by monotypy).

Diagnosis.—Test is similar to *Cryptostephanidium* but differs from it in possessing four spines prolonged from **A**, two **L** and **V**. **D** either wartlike or completely absent. **Ax** usually longer than **D**. Free sagittal ring present or absent in the shell cavity.

Remarks.—This genus is distinguished from other eptingioid genera by possessing four spines.

Tetrarhopalus itoigawai Sugiyama, sp. nov.

Figures 13-4a-6b

Description.—Shell spherical to subspherical, defined by some arches with coarse secondary lattice work. Small nodes often developed at the junctions of lattice bars. **AV** as with genus, delicate, fragile, much thinner than other arches, forming a part of sagittal ring. **A**, two **L** and **V** increasing gradually in thickness to arches, and extending into four spines. Spines rodlike to conical, circular in cross section. They are variable in length, almost equal in shape, and

← **Figure 13**. **1, 2**: *Cryptostephanidium longispinosum* (Sashida). **1**: ESN 146169, KIN 49. **2**: ESN 146168, KIN 49, oblique lateral view. **3**: *Cryptostephanidium* sp. aff. *C. verrucosum* Dumitrica, ESN 146172, KIN 61. **4a-6b**: *Tetrarhopalus itoigawai* gen. et sp. nov. **4a**: ESN 146175, paratype, KIN 56, lateral view. **4b**: oblique lateral view showing free arch **AV** pointed by arrow. **5**: ESN 146173, holotype, KIN 50, front view. **6a**: ESN 146289, paratype, KIN 56, back view, focused on **MB**. **6b**: Focused on **V**. **7, 8**: *Pseudostylosphaera kozuri* sp. nov. **7**: ESN 146191, holotype, KIN 38. **8**: ESN 146290, paratype, KIN 49. All scale bars = 50 μm .

sometimes more or less asymmetrically arranged relative to the sagittal plane. **D** and **Ax** as with genus.

Remarks.—The development of the shell, arches and length of the spines are quite variable in a population from one sample.

Dimensions (in μm).—Based on 27 specimens. Maximum diameter of shell; 70–120. Length of spine; 20–90.

Holotype.—ESN 146173 (Figure 13–5) from KIN 50.

Occurrence.—KIN 49, 50, 52 and 56 (Pn assemblage).

Etymology.—This species is named in honor of Prof. Junji Itoigawa of Nagoya University, whose help and continued encouragement have contributed to the present study.

Family Capunuchosphaeridae De Wever, 1979

Remarks.—The family assignment of the following genera follows Dumitrica (1984, 1985).

Genus *Parasepsagon* Dumitrica, Kozur and Mostler, 1980

Type species.—*P. tetracanthus* Dumitrica, Kozur and Mostler, 1980.

Parasepsagon leptaleus Sugiyama, sp. nov.

Figures 14–4–5b

Description.—Test consisting of one cortical and one medullary shell, having four spines. Internal spicule consisting of **MB**, four basal rays and three or four apical ones. Each end of **MB** with two basal rays and one or two apical ones. Development of apical rays commonly weak. All basal rays extending into spines. The basal rays gradually increase in thickness from proximal verticil (corresponding to the junction of medullary shell) to distal one (corresponding to the junction of cortical shell). The spines are thicker than corresponding internal rays, rod-like, tapered distally, circular in cross section,

arranged at right angles. Their proximal part sometimes four-bladed. Cortical shell discoidal, formed of thin bars, often ambiguously defined. Medullary shell is also obscure in the outline. Differentiation of both shells hardly recognized on poorly preserved materials.

Remarks.—Dumitrica *et al.* (1980) designated that this genus is characterized by having one cortical shell, one medullary shell and four bladed spines. Against the definition, this species lacks completely bladed spine and solid shells, and these features are quite different from previously known species of the genus.

Dimensions (in μm).—Based on 15 specimens. Maximum diameter of cortical shell; 60–130. Length of spine; up to 140.

Holotype.—ESN 146187 (Figures 14–5a, 5b) from KIN 49.

Occurrence.—KIN 35, 37, 40, 49 and 51 (Pn assemblage).

Genus *Pseudostylosphaera* Kozur and Mostler, 1981

Type species.—*P. gracilis* Kozur and Mostler, 1981.

Pseudostylosphaera kozuri Sugiyama, sp. nov.

Figures 13–7, 8

Description.—Test as with genus. Internal spicule consisting of **MB**, four basal rays and three or four apical ones. Each end of **MB** has two basal and one or two apical spines. Two of basal rays, one at either end of **MB**, extending in counter directions and prolonged into equatorial spines outside. They gradually increase in thickness from proximal to distal verticils just like those of *Parasepsagon leptaleus* sp. nov. Two equatorial spines much thicker than corresponding rays, rodlike, tapering distally, with circular cross section. Cortical shell ellipsoidal, formed of loose lattice work, bearing small nodes at the junctions of lattice bars. Medullary shell has much looser lattice work, sometimes fairly

indistinct.

Remarks.—This species is easily distinguished from other species of the genus by its primitive morphologic features. Some individuals lack completely differentiated shells, but the variation is considered to be intraspecific. Two external spines are termed not “polar” but “equatorial” spines just like Cenozoic axoprunins, as discussed in Sugiyama *et al.* (in press).

Dimensions (in μm).—Based on 37 specimens. Major diameter of cortical shell; 60–120. Minor diameter of cortical shell; 50–90. Length of equatorial spine; 45–90.

Holotype.—ESN 146191 (Figure 13-7) from KIN 38.

Occurrence.—KIN 29, 30, 32–40, 47–50, 52 and 54–56 (Pn assemblage).

Etymology.—This species is named after Dr. Heinz Kozur, Hungary, in honor of his great contribution to Paleozoic and Mesozoic micropaleontology.

Pseudostylosphaera sp. A

Figures 14-1, 2

Archaeospongoprimum sp. —Arakawa, 1986, pl. 7, fig. 2.

aff. *Pseudostylosphaera* sp. —Blome *et al.*, 1986, pl. 8, figs. 4, 5.

Description.—Cortical shell subspherical, nodose, pierced by a large number of small pores. Two equatorial spines not in a line, slightly directed downward. They are long, equal in length, gently tapered distally, sometimes slightly curved, and three-bladed. The blades acute, much narrower than grooves, sometimes branched at the most proximal part. Details of medullary shell uncertain.

Remarks.—The general shape of this species is similar to that of *P. tenuis* (Nakaseko and Nishimura, 1979) from which it is distinguished by having equal polar spines. It also differs from other species of the genus by having much more acute ridges and more or less obliquely directed polar spines.

Dimensions (in μm).—Based on 15 speci-

mens. Maximum diameter of cortical shell: 110–150. Length of equatorial spine: up to 220.

Occurrence.—KIN 42, 44, 45, 69 and 71 (Tc assemblage).

Family Polyentactiniidae Nazarov, 1975

Remarks.—Nazarov and Ormiston (1985) tentatively assigned the type genus *Polyentactinia* Foreman, 1963, to the Cenozoic family Orosphaeridae Haeckel. In my Early to Middle Triassic materials, however, none have comparable dimensions to orosphaerids. They attributed the absence of orosphaerids from the Mesozoic probably to extracting procedures. As a matter of fact, however, much more delicate skeletons and fragments are easily obtainable from the Mesozoic strata even through HF treatment. It is thus quite reasonable to separate *Polyentactinia* from the Orosphaeridae based on their stratigraphic distributions.

Genus *Archaeosemantis* Dumitrica, 1978b

Type species.—*A. pterostephanus* Dumitrica, 1978b.

Archaeosemantis cristianensis Dumitrica

Figures 14-3, 6

Archaeosemantis pterostephanus (part.) Dumitrica, 1978b, p. 52, pl. 5, figs. 7, 8.

Archaeosemantis cristianensis Dumitrica, 1982c, p. 423, pl. 1, fig. 11, pl. 3, fig. 11, pl. 4, figs. 5, 7, 11, pl. 6, fig. 2, pl. 7, figs. 3, 12, 13.

Archaeosemantis (?) sp. —Matsuda and Isozaki, 1982, pl. 3, figs. 31, 32.

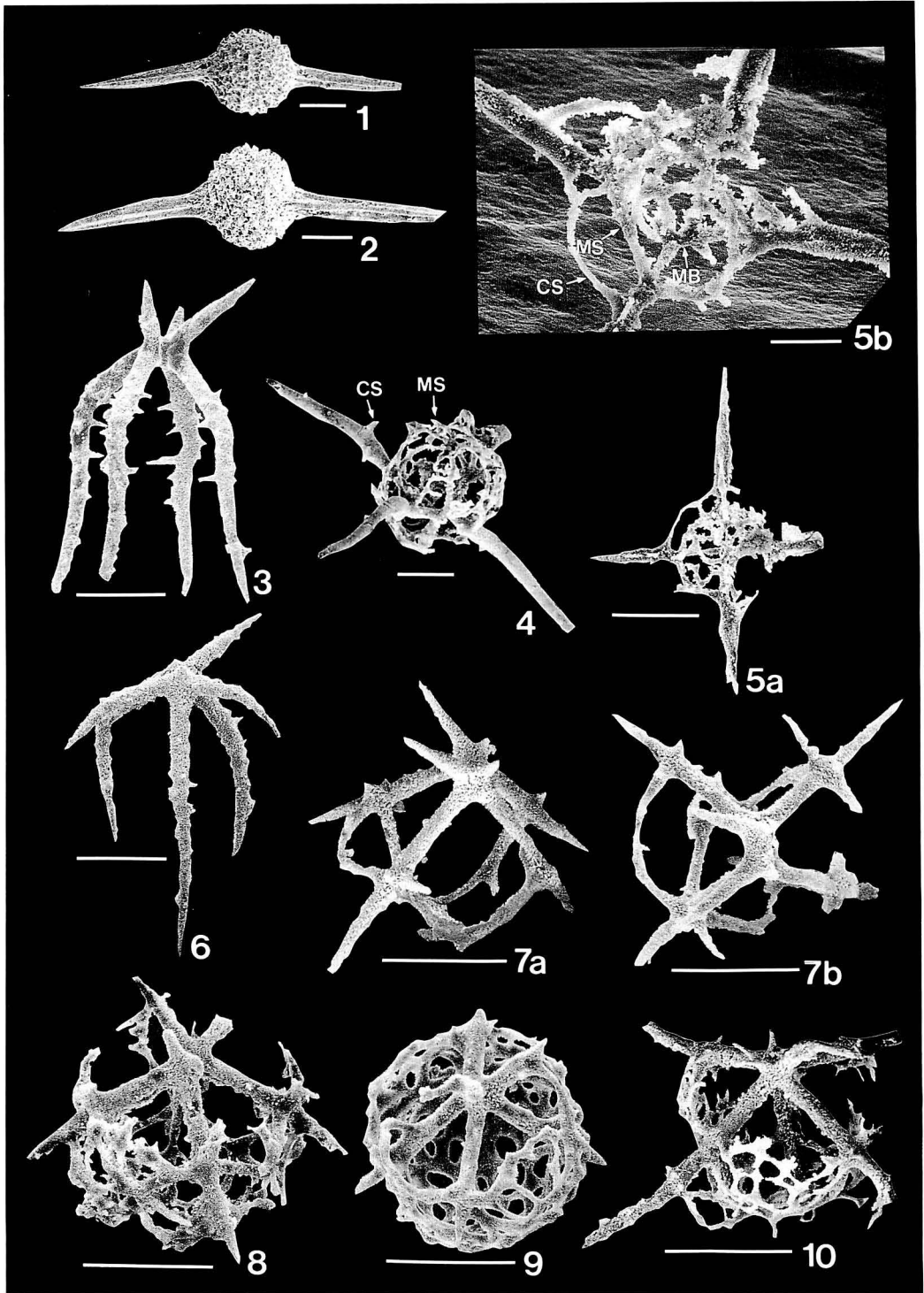
Archaeosemantis venusta Sashida, 1983, p. 171, pl. 36, figs. 1–9. —Sashida, 1991, figs. 5–4–8.

Archaeosemantis sp. aff. *A. venusta* —Sashida, 1991, fig. 5–9.

Archaeosemantis sp. —Sashida, 1991, figs. 5–1–3.

Description.—Two forms of morphologic variation are described below.

Morphotype A.—Four basal spines and two to four apical spines possessing circular cross section and acute tips, extending from both ends of short **MB**. Basal spines, two at each



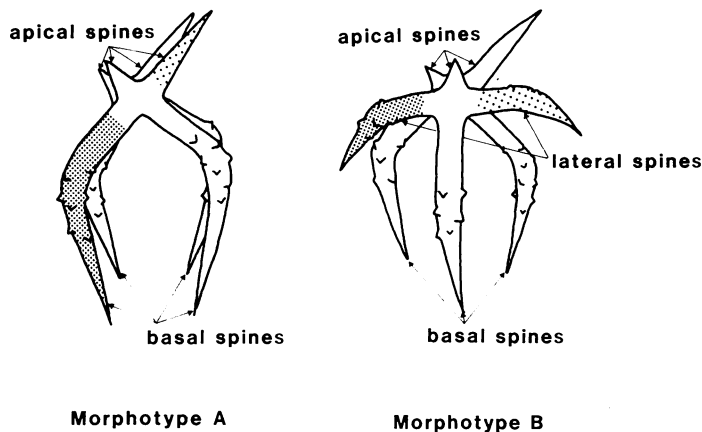


Figure 15. Schematic illustration of two morphotypes of *Archaeosemantis cristianensis*. Dotted basal spine in the morphotype A is homologous with a lateral spine with the same dot pattern in the morphotype B. Dotted apical spine in the morphotype A is homologous with another lateral spine in the morphotype B.

end of **MB**, are almost equal in length, divergent downward approximately 45° from the horizontal. They bent inwardly within the interval between their proximal third and half, and never fuse terminally. They have more or less nodular surface. The nodules developed especially near the bending portion, sometimes forming short conical spinules, and usually disappearing on the distal part of spines. Apical spines, one longer and one shorter at each end of **MB**, are much shorter than basal ones. They are divergent upward approximately 20° to 45° from the horizontal. Two longer spines of one individual are always situated at the same side to a meridional plane passing through **MB**, and so are two shorter ones, so that the whole spicule construction is bilaterally asymmetrical to the meridional plane. The surface of apical spines usually bears faint nodules but varies from smooth to nodular. Shorter apical spines sometimes wart-like or completely absent.

Morphotype B.—Two equal basal spines, one shorter apical spine and one longer apical spine arise from one end of **MB**. Their morphological characters are quite identical to the corresponding half of morphotype A. From the other end of **MB** arise one basal spine, two lateral spines, and one apical spine. The basal spine situated in a meridional plane passing through **MB**, having the same features to the other two extending from the opposite end of **MB**. The two lateral spines more or less nodulated, equal in length to the longer apical spine arising from the opposite end of **MB**, and gently curved downward. The apical spine short, conical, directed upward, sometimes missing.

Remarks.—The spicule constructions of the two above-described morphotypes are schematically illustrated in Figure 15. According to my observations, there are numerous intermediate forms between the morphotypes A and B. The transition from morphotype A to B is caused by the rotation

← **Figure 14.** 1, 2: *Pseudostylosphaera* sp. A. 1: ESN 146178, KIN 45. 2: ESN 146180, KIN 45. 3, 6: *Archaeosemantis cristianensis* Dumitrica. 3: ESN 146194, KIN 38, morphotype A. 6: ESN 146195, KIN 49, morphotype B. 4–5b: *Parasepsagon leptaleus* sp. nov. 4: ESN 146188, paratype, KIN 37, oblique lateral view. 5a: ESN 146187, holotype, KIN 49, basal view. 5b: Oblique lateral view. CS and MS in 4 and 5b mean cortical shell and medullary one, respectively. 7a–10: *Parentactinia nakatsugawaensis* Sashida. 7a: ESN 146197, KIN 49, oblique lateral view. 7b: Apical view. 8: ESN 146291, KIN 49. 9: ESN 146200, KIN 38. 10: ESN 146292, KIN 49, octaradial form. Scale bars: 5b = $20\ \mu\text{m}$; others = $50\ \mu\text{m}$.

of half of morphotype A, which is approximately 45° around the axis of **MB**, and simultaneous shortening of one basal spine. On the basis of the fact that continuous transition is easily traceable in a population, I consider them as phenotypic variations of one and the same species of *A. cristianensis*.

Dimensions (in μm).—Based on 79 specimens. Height of morphotype A; 100–220. Width of morphotype A; 70–150. Height of morphotype B; 100–210. Width of morphotype B; 70–150.

Occurrence.—KIN 2–8, 10, 14–16, 20, 21, 29–40, 47–57, 82–85, 90, 92, 93, 95–100 and 106–111 (Pn assemblage) and KIN 58–61, 64–68 (Hg assemblage).

Genus *Parentactinia* Dumitrica, 1978b

Type species.—*P. pugnax* Dumitrica, 1978b.

Parentactinia nakatsugawaensis Sashida

Figures 14–7a–10

Unnamed spumellaria – Matsuda and Isozaki, 1982, pl. 3, figs. 33–35.

Parentactinia nakatsugawaensis Sashida, 1983, pl. 37, figs. 1–9. –Yeh, 1990, p. 12, pl. 4, fig. 9. –Sashida, 1991, p. 687, figs. 5–15, 16, 6–1, 3–6.

(?) *Pactarentinia koikei* Sashida, 1991, p. 691, figs. 6–2, 8–12.

Description.—Spicule composed of two apical and two basal spines extending from each end of **MB**. Viewed along **MB**, typical construction of spicule shows tetra-radiate profile, but it is sometimes viewed as octa-radiate since the groups of spines radiating from the two ends of **MB** are more or less rotated with respect to one another. The four apical spines usually consisting of two shorter and two longer ones. The former group is conical to rodlike and without verticils, whereas the latter is rodlike, sometimes as long as basal spines, and inclined to have one verticil of spinules as the length increases. All basal spines rodlike, straight, and bearing one verticil of three or four spinules which

more or less curve inward. Because the two shorter apical spines are situated at the same side relative to a meridional plane passing through **MB**, the whole form always exhibits an asymmetrical profile to the meridional plane. Shell loosely latticed, commonly resulted from the amalgamation of the spinules on the basal spines. Secondary meshwork connecting the spinules also developed to a certain degree. This shell is exclusively supported by basal spines and always incomplete in the apical portion. The nature and development of the shell is, however, quite variable. Thus some specimens are exclusively characterized by the development of short, conical and unbranched spinules and completely lack a lattice shell. On the contrary, shell sometimes shows more or less solid aspect, and may be supported by both all basal and longer apical spines.

Remarks.—Recently Sashida (1991) described one new species *Pactarentinia koikei*, which is similar to *P. nakatsugawaensis* but has a shell supported by both basal and apical spines. In accordance with my observation, *P. nakatsugawaensis* has quite wide variation regarding the shell development, thus I consider that they cannot be distinguished only by the development of the shell. Further investigation is necessary with respect to this point. It is very interesting that some individuals, having two long apical spines which are almost equal to basal spines, are similar to the species of the nassellarian genus *Tandarnia* Dumitrica, 1982c, since the longer spines seem to correspond to **L** and **I**, whereas the shorter ones are homologous with **D** and **Ax**. The variational rotation around the axis of **MB** indicates the phylogenetic closeness of this species and *Archaeosemantis cristianensis*.

Dimensions (in μm).—Based on 38 specimens. Diameter of shell; 70–150. Length of apical spine; up to 140. Length of basal spine; 40–200.

Occurrence.—KIN 2–8, 11, 13, 14, 19–21, 29–40, 47–57, 76, 82–85, 89–93, 95–100 and

106-111 (Pn assemblage), KIN 59, 64-66 and 68 (Hg assemblage) and KIN 69, 71-73 (Tc assemblage).

Parentactinia okuchichibuensis (Sashida)

Figures 16-2a, 2b

Archaeothamnulus okuchichibuensis Sashida, 1991, p. 687, figs. 5-10-14.

Remarks.—Sashida (1991) mentioned that this species is characterized by having point-centered spines, four basal and one apical. However, most specimens from Mt. Kinkazan exhibit bar-centered profile with four basal and one or two apical spines. Judging from the fact and its general shape, this species is closely related to *P. inerme* Dumitrica, 1978b.

Occurrence.—KIN 30, 34-38, 40, 48-50, 52, 54, 97 and 108 (Pn assemblage).

Parentactinia ramosa (Sashida)

Figures 16-1

Archaeothamnulus ramosus Sashida, 1983, pl. 37, figs. 10-12.

Remarks.—This species always exhibits bar-centered profile, and the morphologic variation shows the development of archlike structure connecting distal portions of basal spines. Thus this species should be assigned to *Parentactinia* rather than *Archaeothamnulus* Dumitrica, 1982c (= *Triassothumbnus* Kozur and Mostler, 1981).

Occurrence.—KIN 37, 38 and 56 (Pn assemblage).

Genus *Polyentactinia* Foreman, 1963

Type species.—*P. craticulata* Foreman, 1963.

Polyentactinia (?) *biacus* Sugiyama, sp. nov.

Figures 16-3-5b

Description.—Shell single, spherical to slightly ellipsoidal, loosely latticed, comprising an internal spicule. Lattice bars circular

to oval in cross section, often bearing nodes at the junctions. **MB** eccentrically situated in the shell. Four rays radiating from each end of **MB**. Two of them, opposite relative to **MB**, are tied to spines which arranged either almost in a line or at an obtuse angle. Spines rodlike to conical, tapered, thicker than corresponding rays. One spine, situated nearer to **MB** than the other, is commonly shorter. The other six rays connected with lattice bars, and not extending outside the shell.

Remarks.—This species is similar to *Pseudostylosphaera kozuri* sp. nov. but differs from it in lacking a medullary shell. The development of lattice shell is variable, and the direction of the spines is also unstable.

Dimensions (in μm).—Based on 29 specimens. Diameter of shell; 70-120. Length of longer spine; 40-100. Length of shorter spine; up to 40.

Holotype.—ESN 146204 (Figure 16-4) from KIN 50.

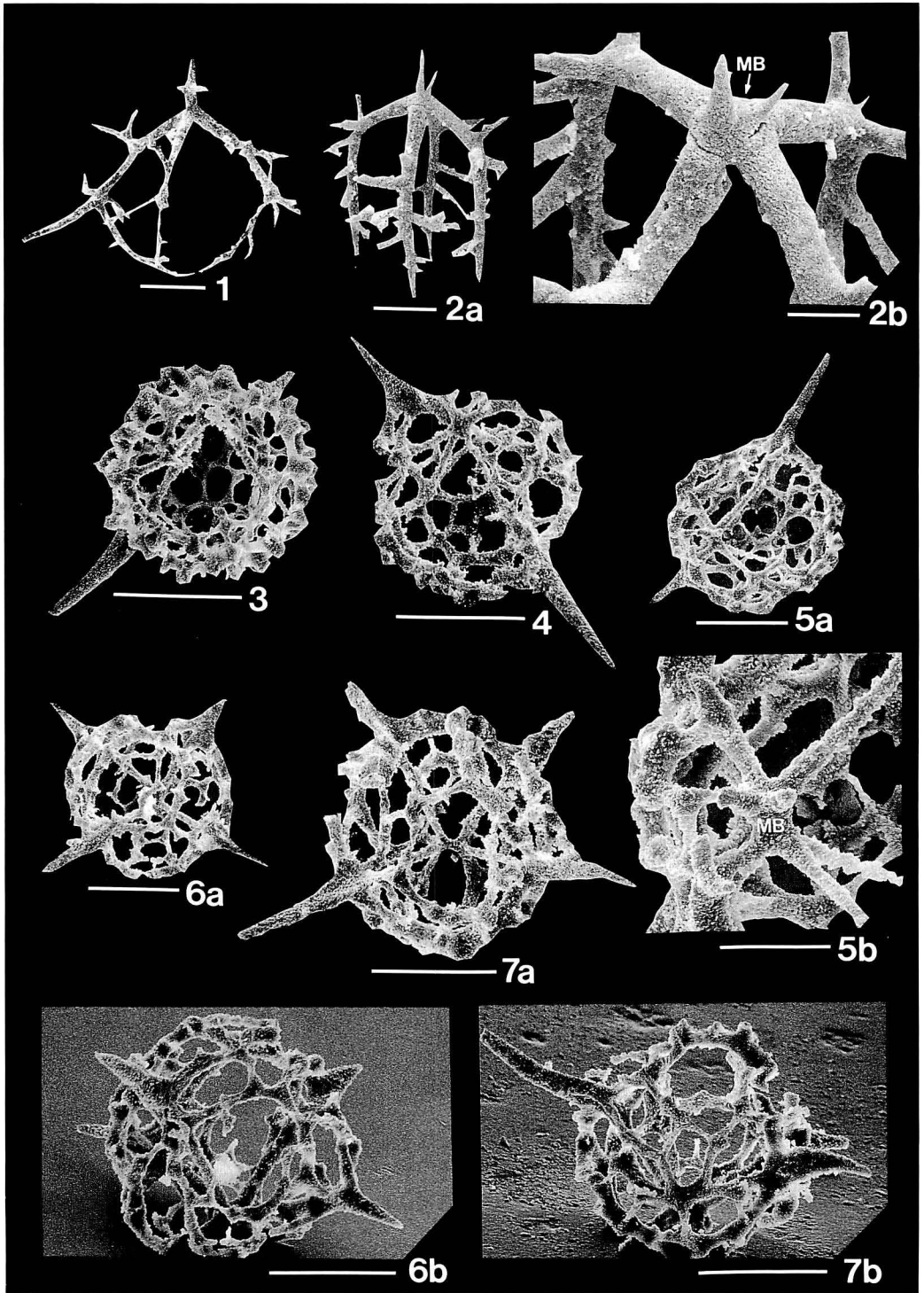
Occurrence.—KIN 31, 35-37, 47-52 and 54 (Pn assemblage).

Polyentactinia (?) *crux* Sugiyama, sp. nov.

Figures 16-6a-7b

Description.—Shell single, nearly spherical, loosely latticed, comprising an internal spicule, with four spines situated in the equatorial plane. Lattice bars circular to oval in cross section. Small nodes present at the junctions of the lattice bars. **MB** is eccentrically situated in the shell, each end of which has two apical and two basal rays. The former rays much shorter than the latter, tied to the lattice bars, whereas the latter ones extend into spines which are conical to rodlike, variable in length, and much thicker than corresponding rays.

Remarks.—This species resembles *Parasepsagon leptaleus* sp. nov. but differs from it in lacking a medullary shell. It is distinguished from *P. (?) biacus* sp. nov. by having four spines rather than two.



Dimensions (in μm).—Based on 17 specimens. Maximum diameter of shell; 70–120. Length of spine; up to 90.

Holotype.—ESN 146207 (Figures 16–6a, 6b) from KIN 49.

Occurrence.—KIN 30, 35–37, 40, 49–51 and 53 (Pn assemblage).

Polyentactinia (?) spp.

Figures 17–1, 2

Remarks.—In the Pn assemblage there are numerous species provisionally assignable to *Polyentactinia* but none are identified at the specific level in this study.

Incerta Family

Genus *Pentabelus* Sugiyama, gen. nov.

Etymology.—From the Greek *penta*, five, and *belos*, dart, masculine gender.

Type species.—*P. furutanii* Sugiyama, sp. nov. (by monotypy).

Diagnosis.—Internal spicule composed of **MB**, **A**, **D**, two **L**, two **I** and **Ax**. **V** missing. Five spines corresponding to the prolongations of **A**, two **L** and two **I**. **D** and **Ax** short, connected with spherical shell, sometimes absent.

Remarks.—Nassellarian descriptive terminology is conventionally used for this genus as for the eptingiid genera. It is, however, distinguished from the latter by lacking **V** and having spines extending from the two **I**. Detailed character of the shell is not established at this time. The family assignment is uncertain.

Pentabelus furutanii Sugiyama, sp. nov.

Figures 17–3, 5a, 5b

Description.—Shell primitive, spherical, formed of two **Al**, two **Li** and **Ll** and coarse, thinner secondary lattice work connecting arch structure. Frontal side of internal spicule also contributes to form a part of the shell. Lattice bars delicate, circular to ellipsoidal in cross section, bearing small nodes at the junctions. **A** prolonged into a long, rodlike spine. Two **L** and two **I** weakly bent frontally at the verticil of arches, and prolonged into four acute spines of which the ones arising from the two **I** are much shorter. All spines thicker than corresponding rays, tapered distally to a point, circular in cross section. **D**, **V** and **Ax** as with genus.

Remarks.—The occurrence of this species is rare in the Pn assemblage.

Dimensions (in μm).—Based on 15 specimens. Diameter of shell; 70–115. Length of spine arising from **A**: 65–120. Length of spine arising from **L**: 20–65. Length of spine arising from **I**; up to 40.

Holotype.—ESN 146209 (Figures 17–5a, 5b) from KIN 37.

Occurrence.—KIN 37, 40, 47 and 51 (Pn assemblage).

Etymology.—This species is named after Dr. Hiroshi Furutani of Hyogo Prefectural Board of Education in honor of his great contribution to the study of Paleozoic radiolarians.

Order Spumellaria

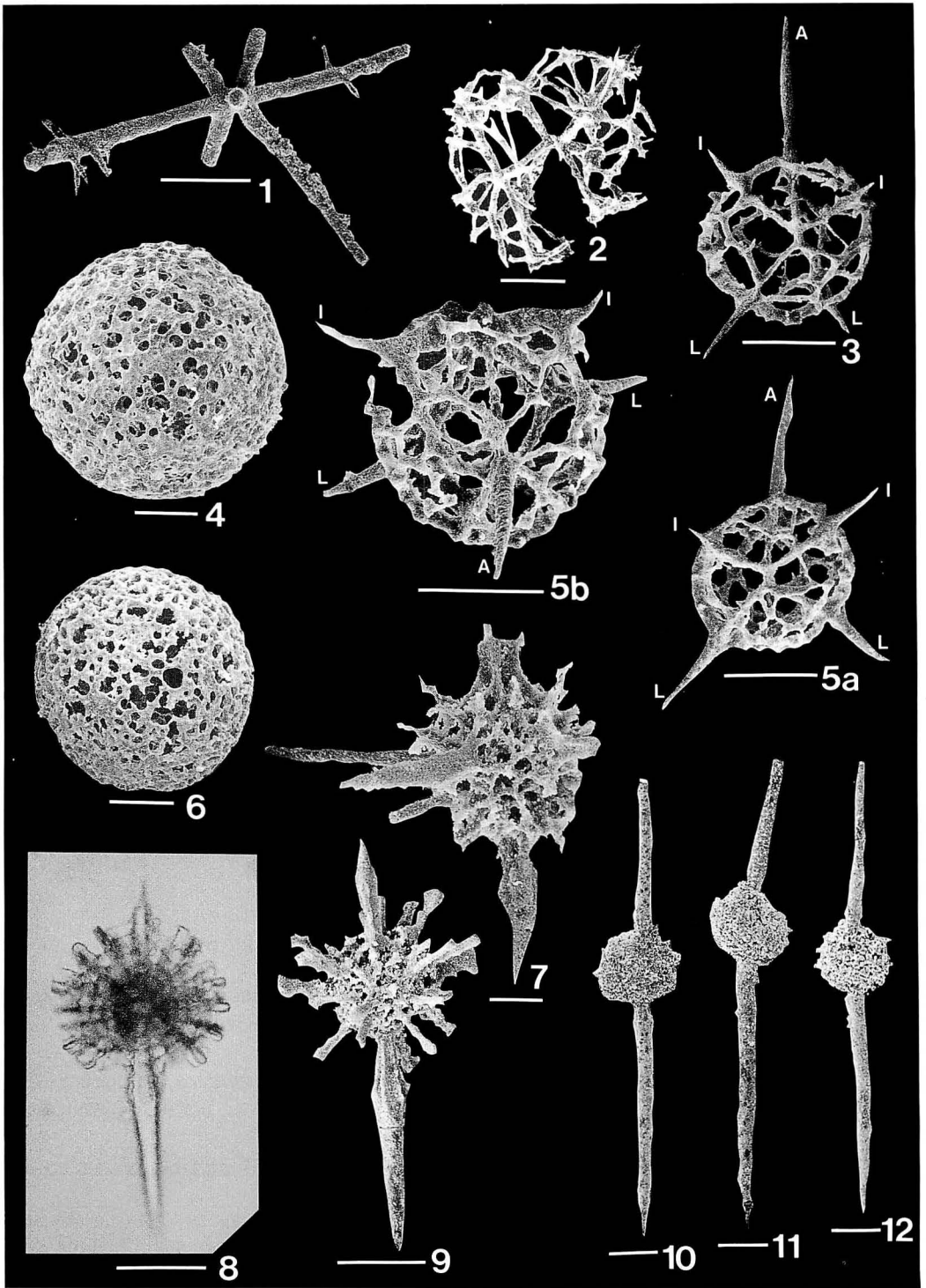
Family Actinommidae Haeckel, 1862, emend. Riedel, 1967b

Genus *Cenosphaera* Ehrenberg, 1854

Type species.—*C. plutonis* Ehrenberg, 1854.

Cenosphaera andoi Sugiyama, sp. nov.

← **Figure 16**. **1**: *Parentactinia ramosa* (Sashida), ESN 146185, KIN 37. **2a**, **2b**: *Parentactinia okuchichibuensis* (Sashida), ESN 146186, KIN 50. **3–5b**: *Polyentactinia* (?) *biacus* sp. nov. **3**: ESN 146206, paratype, KIN 49. **4**: ESN 146204, holotype, KIN 50. **5a**: ESN 146205, paratype, KIN 49. **5b**: Enlargement of **MB**. **6a–7b**: *Polyentactinia* (?) *crux* sp. nov. **6a**: ESN 146207, holotype, KIN 49, basal view. **6b**: oblique lateral view. **7a**: ESN 146208, paratype, KIN 50, oblique basal view. **7b**: Lateral view.



Figures 17-4, 6

Description.—Single shell remarkably porous, with more or less rugged surface. Pores variable in shape, circular to irregular. Pore frame variable in width, incomplete in many parts, and often bearing small nodes.

Remarks.—This species is easily distinguished from *C. clathrata* Parona, 1890, by its incomplete lattice work.

Dimension (in μm).—Based on 55 specimens. Diameter of shell; 60-250.

Holotype.—ESN 146215 (Figure 17-4) from KIN 51.

Occurrence.—KIN 29, 31, 35-38, 40, 47 and 49-52 (Pn assemblage).

Etymology.—This species is named in honor of Mr. Hideyuki Ando who first studied the geology of Mt. Kinkazan.

Family Oertlispongidae Kozur and Mostler, 1980, emend. Kozur and Mostler 1981

Genus *Oertlispongus* Dumitrica, Kozur and Mostler, 1980

Type species.—*O. inaequispinosus* Dumitrica, Kozur and Mostler, 1980.

Oertlispongus diacanthus Sugiyama, sp. nov.

Figures 17-10—12

Oertlispongus sp. - Bragin, 1991, pl. 1, fig. 19.

Description.—Shell spongy, fragile, relatively small, spherical to subspherical, composed of numerous concentric layers, and bearing two polar spines and no conspicuous minor ones. The innermost structure of shell is unknown. Polar spines long, straight or slightly curved in the distal portion, tapered distally, always circular in cross section;

proximal part inserted in the shell and abruptly tapered to form a short cone on which numerous thin thorns regularly arranged in transverse rows are observable when the shell is partly dissolved.

Remarks.—The occurrence of a completely preserved individual, retaining a spongy shell, is very rare. The well-preserved part of the skeleton is usually restricted to the polar spines as is the case with other oertlispongids. Completely preserved individuals are easily distinguished from other oertlispongids by its two nearly straight polar spines. Such a feature of the polar spines is not applicable to any of previously designated oertlispongid genera. In this study, therefore, the original diagnosis of *Oertlispongus* is used in an enlarged meaning.

Dimensions (in μm).—Based on 51 specimens. Diameter of shell; 70-135. Length of polar spine; 160-330.

Holotype.—ESN 146229 (Figure 17-10) from KIN 45.

Occurrence.—KIN 42-45 and 96 (Tc assemblage).

Genus *Pegoxystris* Sugiyama, gen. nov.

Etymology.—From the Greek *pegos*, solid, and *xystris*, scraper, feminine gender.

Including species.—*P. mizutanii* Sugiyama sp. nov. (type species) and an indeterminate species *P. sp. A.*

Diagnosis.—Shell composed of about five concentric layers connected with one another by numerous beams radiating from the innermost layer in all directions. The shell surface bears relatively short, delicate minor spines which are prolongations of the beams and variable in length and shape of the cross section. Two polar spines stout, long, usu-

← **Figure 17.** 1, 2: *Polyentactinia* (?) spp. 1: ESN 146293, KIN 49. 2: ESN 146203, KIN 47. 3, 5a, 5b: *Pentabelus furutanii* gen. et sp. nov. 3: ESN 146210, paratype, KIN 37. 5a: ESN 146209, holotype, KIN 37. 5b: Apical view. 4, 6: *Cenosphaera andoi* sp. nov. 4: ESN 146215, holotype, KIN 51. 6: ESN 146214, paratype, KIN 37. 7: *Pegoxystris* sp. A., ESN 146219, KIN 49. 8, 9: *Pegoxystris mizutanii* gen. et sp. nov. 8 ESN 146221, holotype, KIN 37. 9: ESN 146223, paratype, KIN 50. 10-12: *Oertlispongus diacanthus* sp. nov. 10: ESN 146229, holotype, KIN 45. 11: ESN 146294, paratype, KIN 45. 12: ESN 146295, paratype, KIN 45. All scale bars = 50 μm .

ally unequal in length, extending from the center of shell, sometimes deviated from the polar axis; proximal part increasing in thickness from the innermost layer to outside of the shell, with polygonal cross section, sometimes slightly bladed; middle to distal part circular in cross section, distally tapering. With or without other spines extending from the equatorial portion of shell.

Remarks.—This genus differs from other oertlispongid genera in having numerous minor spines which are prolongations of beams and fewer concentric layers. The concentric structure of this genus also resembles that of Paleozoic genera *Copicyntra* Nazarov and Ormiston, 1985, and *Provisocyntra* Nazarov and Ormiston, 1987. This genus is, however, distinguished from them by having two characteristic polar spines.

Pegoxystris mizutanii Sugiyama, sp. nov.

Figures 17-8, 9

Description.—Test as with genus, without equatorial spines. Minor spines densely distributed around the equatorial portion of shell. They are circular to polygonal, sometimes bladed in cross section. Two polar spines commonly in a line, sometimes at an obtuse angle.

Remarks.—This species is characteristic for the Pn assemblage.

Dimensions (in μm).—Based on 25 specimens. Diameter of shell; 60–100. Length of longer polar spine; 70–200. Length of shorter polar spine; up to 130.

Holotype.—ESN 146221 (Figure 17-8) from KIN 37.

Occurrence.—KIN 29–31, 33, 35–40, 49, 51, 52, 56 and 109 (Pn assemblage).

Etymology.—This species is named after Prof. Shinjiro Mizutani of Nagoya University in honor of his great contribution to the geology of the Mino terrane and Mesozoic radiolarians.

Pegoxystris sp. A

Figures 17-7

Remarks.—This species is distinguished from *P. mizutanii* by having a few or several equatorial spines.

Occurrence.—KIN 29, 35–37, 40, 49 and 52 (Pn assemblage).

Incerta Family

Genus *Plafkerium* Pessagno, 1979

Type species.—*P. abbotti* Pessagno, 1979.

Plafkerium (?) *antiquum* Sugiyama, sp. nov.

Figures 18-4–6

Staurosphaera (?) sp. B-Yao *et al.*, 1980, pl. 1, fig. 6.

(?) *Staurosphaera* (?) sp. A-Yao *et al.*, 1980, pl. 1, fig. 5.

Staurodoras (?) sp. -Mizutani and Koike, 1982, pl. 4, figs. 1, 2.

(?) *Staurodoras* (?) sp. -Sato *et al.*, 1986, pl. 1, fig. 3.

Description.—Cortical shell subspherical, more or less compressed, thick, spongy, composed of reticulated framework, consisting at least of two layers; inner layer with densely arranged small, polygonal to circular pores; outer layer with rather loose pore frames which bear relatively large, irregularly shaped pores and small nodes at their junctions. Details of medullary shell not known. Four coplanar spines not twisted, commonly at right angles; distal part thin, needlelike; middle part rodlike or three-bladed: proximal part three-bladed. One spine is often longer than the others. The blades on spines often reduced to thin, cylindrical bars which may be branched at the most proximal part of the spines. One of the branches on a spine often extends directly toward one from adjacent spine to form a marginal ridge. Four marginal ridges surround the cortical shell in one plane resulting in a square outline. The other branches connected with the pore frames of the cortical shell.

Remarks.—This species is distinguished from previously known species of the genus by its simple, not twisted spines. It seems

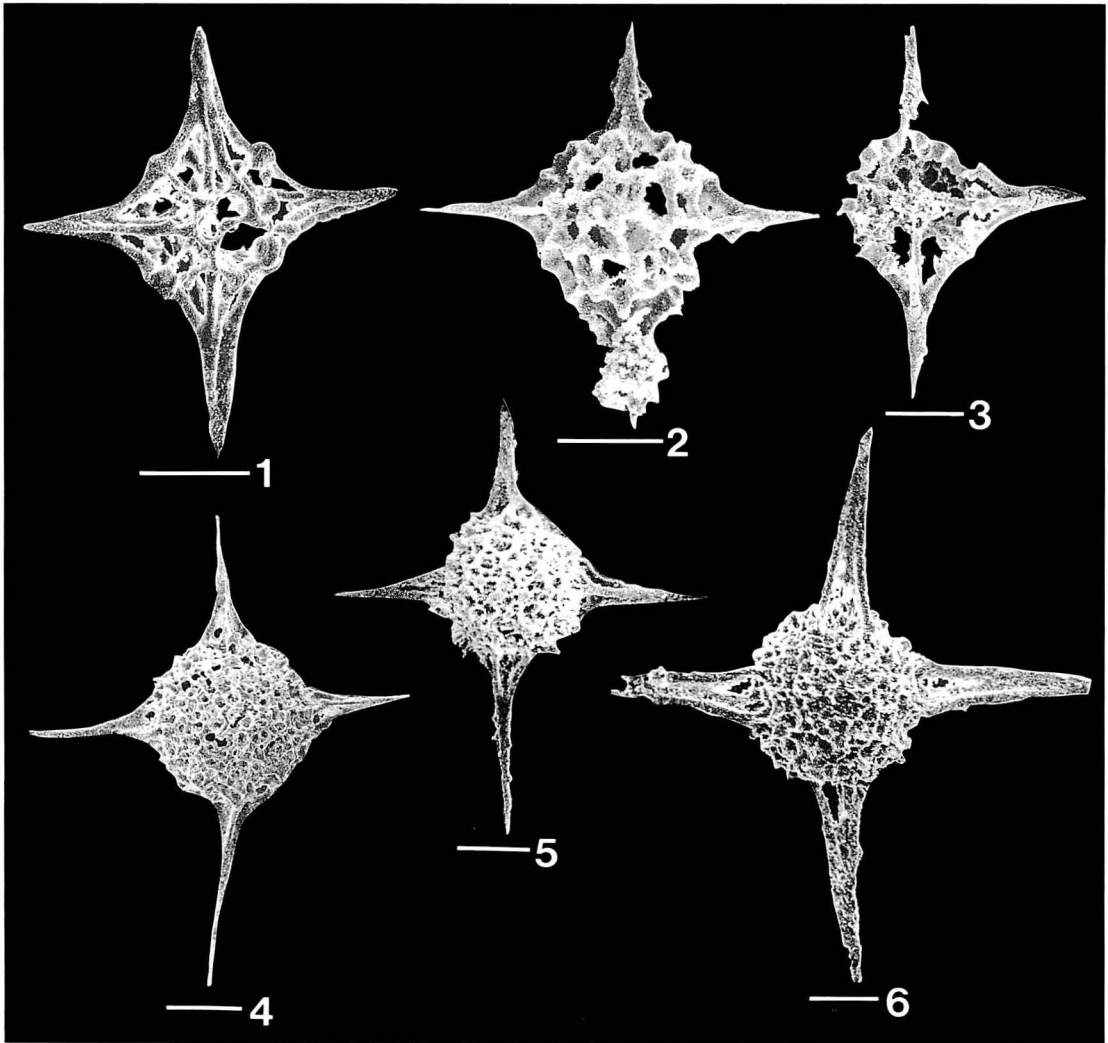


Figure 18. 1-3: *Tiborella agria* sp. nov. 1: ESN 146232, paratype, KIN 38. 2: ESN 146231, holotype, KIN 40. 3: ESN 146230, paratype, KIN 40. 4-6: *Plafkerium* (?) *antiquum* sp. nov. 4: ESN 146233, paratype, KIN 40. 5: ESN 146296, paratype, KIN 56. 6: ESN 146234, holotype, KIN 61.

that two morphotypic variations are present: One is characterized by spines bladed only in the proximal part, whereas the other has nearly complete bladed spines. The former type commonly occurs in the Pn assemblage and the latter type is abundant in the Hg and Tc assemblages.

Dimensions (in μm).—Based on 19 specimens. Diameter of cortical shell in the plane of spines; 100-160. Length of spine; 70-190.

Holotype.—ESN 146234 (Figure 18-6) from KIN 61.

Occurrence.—KIN 29, 35, 39, 40, 54 and 56 (Pn assemblage), KIN 59-62 and 64-68 (Hg assemblage) and KIN 42, 44-46, 69 and 71-73 (Tc assemblage).

Genus *Tiborella* Dumitrica,
Kozur and Mostler, 1980

Type species.—*T. magnidentata* Dumitrica, Kozur and Mostler, 1980.

Tiborella agria Sugiyama, sp. nov.

Figures 18-1-3

Description.—Cortical shell subspherical, more or less compressed, latticed, bearing nodes at the junctions of lattice bars, and having circular to irregularly shaped pores. Medullary shell is delicate and somewhat spongy, but its detailed structure is uncertain owing to the poor preservation. Four cylindrical rays located in a plane, along two rectangular axes, connecting medullary shell with cortical one, and extending into spines which are equal in shape and not twisted. The distal to middle part of spines generally thin, rodlike to slightly bladed, while the proximal one always bears four prominent blades of which two are in the equatorial plane and the other two are in a perpendicular plane. The equatorial blades extending into those on adjacent spines to form four marginal ridges on the side of cortical shell. The perpendicular blades extending to the lattice bars forming the cortical shell.

Remarks.—This species differs from *T. magnidentata* in having rodlike spines rather than twisted ones. It is also distinguished from *Cecrops floridus* Nakaseko and Nishimura, 1979, by lacking twisted spines with blunt or club-shaped distal ends.

Dimensions (in μm).—Based on 25 specimens. Diameter of cortical shell; 75-110. Diameter of medullary shell; 20-40. Length of spine; 30-85.

Holotype.—ESN 146231 (Figure 18-2) from KIN 40.

Occurrence.—KIN 32, 37, 38, 40, 49 and 56 (Pn assemblage).

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References

- Ando, H., 1987: On the Permian clastic rocks from Mt. Kinkazan Area, Gifu City. *Geol. Soc. Japan, Abstracts with Programs, 94th Ann. Meet.*, p. 278. (in Japanese)
- , Tsukamoto, H. and Saito M., 1991: Permian radiolarians in the Mt. Kinkazan area, Gifu City, central Japan. *Bull. Mizunami Fossil Mus.*, no. 18, p. 101-106, pl. 9. (in Japanese with English abstract)
- Arakawa, R., 1986: Upper Paleozoic and Mesozoic strata in the southeastern part of the Ashio Mountains. *Bull. Tochigi Pref. Mus.*, no. 3, p. 1-37. (in Japanese with English abstract)
- Blome, C.D., 1983: Upper Triassic Capnuchosphaeridae and Capnodocinae (Radiolaria) from east-central Oregon. *Micropaleontology*, vol. 29, no. 1, p. 11-49, pls. 1-11.
- , 1984: Upper Triassic Radiolaria and radiolarian zonation from western North America. *Bull. Amer. Paleont.* vol. 85, no. 318, p. 1-88.
- , Jones, D.L., Murchey, B.L. and Liniecki, M., 1986: Geologic implications of radiolarian-bearing Paleozoic and Mesozoic rocks from the Blue Mountains province, Eastern Oregon. In, T.L. Vallier, T.L. and Brooks, H.C., *Geologic Implications of Paleozoic and Mesozoic Paleontology and Biostratigraphy, Blue Mountains Province, Oregon and Idaho. U.S. Geol. Surv. Prof. Paper* 1435, p. 79-93, pls. 8.1-8.3.
- , Moore, P.R., Simes, J.E. and Watters, W.A.,

- 1987: Late Triassic Radiolaria from Phosphatic Concretions in the Torlesse Terrane, Kapiti Island, Wellington. *New Zealand Geol. Surv. Record*, no. 18, p. 103-109.
- Cheng, Y-N., 1986: Taxonomic Studies on Upper Paleozoic Radiolaria. *Natn. Mus. Nat. Sci., Taiwan, Spec. Publ.*, no. 1, 311 p.
- , 1989: Upper Paleozoic and Lower Mesozoic Radiolarian Assemblages from the Busuanga Islands, North Palawan Block, Philippines. *Bull. Natn. Mus. Nat. Sci., Taiwan*, no. 1, p. 129-175.
- Deflandre, M.G., 1963: *Pylentonema*, nouveau genre de Radiolaire du Viséen: Sphaerellaire ou Nassellaire? *C. R. Acad. Sci., Paris*, ser. D, vol. 257, p. 3981-3984.
- De Wever, P., 1981: Une nouvelle Sous-famille, les Poulpinae, et quatre nouvelles espèces de *Saitoum* Radiolaires mésozoïques téthysiens. *Géobios*, no. 14 (1), p. 5-15.
- , Sanfilippo, A., Riedel, W.R. and Gruber, B., 1979: Triassic radiolarians from Greece, Sicily and Turkey. *Micropaleontology*, vol. 25, no. 1, p. 75-110, pls 1-7.
- Dumitrica, P., 1978a: Family Eptingiidae n. fam., extinct Nassellaria (Radiolaria) with sagittal ring. *D. S. Inst. Geol. Geofiz.*, vol. 64, p. 27-38, pls. 1-4.
- , 1978b: Triassic Palaeosceniidae and Entactiniidae from the Vicentinian Alps (Italy) and Eastern Carpathians (Romania). *Ibid.*, vol. 64, p. 39-54, pls. 1-5.
- , 1982a: Triassic Oertlisponginae (Radiolaria) from Eastern Carpathians and Southern Alps. *Ibid.*, vol. 67, p. 57-74, pls. 1-12.
- , 1982b: Foremanellinidae, a new family of Triassic Radiolaria. *Ibid.*, vol. 67, p. 75-82, pls. 1-3.
- , 1982c: Middle Triassic spicular Radiolaria. *Rev. Española Micropaleont.*, vol. 14, p. 401-428.
- , 1984: Systematics of sphaerellarian radiolarians. In, Petrushevskaya, M.G. and Stepanjants, S.D., *Morfologiya, Ecologiya i evolyutsiya radiolyarii*. Materialy IV simpoziuma evropeiskikh radiolyaristov EURORAD-IV, p. 91-102 Nauka, Leningrad. (in Russian)
- , 1991: Middle Triassic Tripedurnulidae, n. fam. (Radiolaria) from the eastern Carpathians (Romania) and Vicentinian Alps (Italy). *Rev. Micropaleont.*, vol. 34, no. 4, p. 261-278.
- , Kozur, H. and Mostler, H.,: Contribution to the radiolarian fauna of the Middle Triassic of the Southern Alps. *Paläont. Mitt. Innsbruck*, vol. 10, no. 1, p. 1-46.
- Ehrenberg, G., 1854: *Mikrogeologie*. Leipzig, xxviii+374 pp. Atrls, 31 p., 41 pls. Fortsetzung (1856), 88 pp.
- Foreman, H.P., 1963: Upper Devonian Radiolaria from the Huron member of the Ohio shale. *Micropaleontology*, vol. 9, no. 3, p. 267-304, pls 1-9.
- Goričan, Š. and Buser, S., 1988/1989: Middle Triassic radiolarians from Slovenia (Yugoslavia). *Geolojija*, 31, 32, p. 133-197.
- Haeckel, E., 1862: Die Radiolarien (Rhizopoda Radiolaria). Eine Monographie. xiv+572 p., iv+35 pls. Reimer, Berlin.
- Hertwig, R., 1879: Der Organismus der Radiolarien. In, Fischer, G., p. I-IV, 1-149, pls. 1-10. Jena.
- Imoto, N., 1984: Late Paleozoic and Mesozoic cherts in the Tamba Belt, Southwest Japan (Part 1). *Bull. Kyoto Univ. Educ.*, sec. B, no. 65, p. 15-40.
- Ishiga, H. 1986: Late Carboniferous and Permian radiolarian biostratigraphy of southwest Japan. *Jour. Geosci., Osaka City Univ.*, vol. 29, art. 3, p. 89-100.
- , Kito, T. and Imoto, N., 1982a: Late Permian radiolarian assemblages in the Tamba district and an adjacent area, Southwest Japan. *Earth Sci. (Chikyu Kagaku)*, vol. 36, no. 1, p. 10-22.
- , — and —, 1982b: Middle Permian radiolarian assemblages in the Tamba district and an adjacent area, Southwest Japan. *Ibid.*, no. 5, p. 272-281.
- Kido, S., 1982: Occurrence of Triassic chert and Jurassic siliceous shale at Kamiyo, Gifu Prefecture, central Japan. *News of Osaka Micropaleont., Spec. Vol.*, no. 5, p. 135-151. (in Japanese with English abstract)
- Kishida, Y. and Sugano, K., 1982: Radiolarian zonation of Triassic and Jurassic in outer side of southwest Japan. *Ibid.*, p. 271-300. (in Japanese with English abstract)
- Koike, T., 1981: Biostratigraphy of Triassic conodonts in Japan. *Sci. Rep., Yokohama Natn. Univ.*, sec. II, no. 28, p. 25-42.
- Kojima, S. and Mizutani, S., 1987: Triassic and Jurassic Radiolaria from the Nadanhada Range, northeast China. *Trans. Proc. Palaeont. Soc. Japan*, N.S., no. 148, p. 256-275.
- Kozur, H., 1984: New radiolarian taxa from the Triassic and Jurassic. *Geol. Paläont. Mitt. Innsbruck*, vol. 13 (2), p. 49-88.
- and Mostler, H., 1972: Beiträge zur Erforschung der mesozoischen Radiolarien. Teil I: Revision der Oberfamilie Coccodiscacea HAECKEL 1862 emend. und Beschreibung ihrer triassischen Vertreter. *Ibid.*, vol. 2 (8/9), p. 1-60.
- and —, 1978: *Ibid.*. Teil II: Oberfamilie Trematodiscacea HAECKEL 1862 emend. und Beschreibung ihrer triassischen Vertreter. *Ibid.*, vol. 8, p. 123-182.
- and —, 1979: *Ibid.*. Teil III: Die Ober-

- familien Actinomacea HAECKEL 1862 emend., Artiscacea HAECKEL 1882, Multiarcusellacea nov. der Spumellaria und triassische Nassellaria. *Ibid.*, vol. 9, p. 1-132.
- and —, 1981: *Ibid.*. Teil VI: Thalassosphaeracea HAECKEL, 1862, Hexastylacea HAECKEL, 1882 emend. PETRUSEVSKAJA, 1979, Sponguracea HAECKEL, 1862 emend. und weitere triassische Lithocycliacea, Trematodiscacea, Actinomacea und Nassellaria. *Ibid.*, Sonderbd., p. 1-208.
- and —, 1982: Entactinaria subordo. nov., a new radiolarian suborder. *Ibid.*, vol. 11/12, p. 399-414.
- and —, 1989: Radiolarien und Schwammskelern aus dem Unterperm des Vorurals. *Ibid.*, sonderbd. 2, p. 147- 275.
- Lahm, B., 1984: Spumellarienfaunen (Radiolaria) aus den mitteltriassischen Buchensteiner-Schichten von Recoaro (Norditalien) und den obertriassischen Reifingerkalken von Großreifling (Österreich)-Systematik —Stratigraphie-. *Münchner Geowiss. Abh.*, (A), 1, 161 pp.
- Matsuda, T. and Isozaki, Y., 1982: Radiolarians around the Triassic-Jurassic boundary from the bedded chert in the Kamiaso area, Southwest Japan. Appendix: "Anisian" radiolarians. *News of Osaka Micropaleont., Spec. Vol.*, no. 5, p. 93-101. (in Japanese with English abstract)
- Mizutani, S., 1990: Mino Terrane. In, Ichikawa, K. et al., *Pre-Cretaceous Terranes of Japan*, publication of IGCP Project No. 224, p. 121-135.
- and Koike, T., 1982: Radiolarians in the Jurassic shale and in the Triassic bedded chert of Unuma, Kagamigahara City, Gifu Prefecture, Central Japan. *News of Osaka Micropaleont., Spec. Vol.*, no. 5, p. 117-134. (in Japanese with English abstract)
- Nakaseko, K. and Nishimura, A., 1979: Upper Triassic Radiolaria from Southwest Japan. *Sci. Rep., Coll. Educ. Osaka Univ.*, vol 28, no. 2, p. 61-109.
- Nazarov, B.B., 1975: Lower and Middle Paleozoic Radiolaria of Kazakhstan. *Akad. Nauk SSSR, Ordena Trudovogo Krasnogo Znameni Geol. Inst., Trudy*, vol. 275, p. 1-202, pls. 1-21. (in Russian)
- and Ormiston, A.R., 1985: Radiolaria from the Late Paleozoic of the southern Urals, USSR and West Texas, USA. *Micropaleontology*, vol. 31, no. 1, p. 1-54, pls. 1-6.
- and —, 1987: A new Carboniferous radiolarian genus and its relation to the multishelled entactiniids. *Ibid.*, vol. 33, no. 1, p. 66-73, pls. 1, 2.
- Nishizono, Y., Ohishi, A., Sato, T. and Murata, M., 1982: Radiolarian fauna from the Paleozoic and Mesozoic formations, distributed along the mid-stream of Kuma River, Kyushu, Japan. *News of Osaka Micropaleont., Spec. Vol.*, no. 5, 311-326. (in Japanese with English abstract)
- Otsuka, T., 1988: Paleozoic-Mesozoic sedimentary complex in the eastern Mino Terrane, Central Japan and its Jurassic tectonism. *Jour. Geosci., Osaka City Univ.*, vol. 31, art. 4, p. 63-122.
- Parona, D.F., 1890: Radiolarie nei noduli selciosi del calcare giurese di Cittiglio presso Laveno. *Soc. Geol. Italiana, Boll.*, vol. 9 (1), p. 1-46, pls. 1-6.
- Pessagno, E.A., Jr., Finch, W. and Abbott, P.M., 1979: Upper Triassic Radiolaria from the San Hipolito Formation, Baja California. *Micropaleontology.*, vol. 25, no. 2, p. 160-197, pls. 1-9.
- and Blome, C.D., 1980: Upper Triassic and Jurassic Pantanellinae from California, Oregon and British Columbia. *Ibid.*, vol. 26, no. 3, p. 225-273, pls. 1-11.
- Petrushevskaya, M.G., 1971: On the natural system of Polycystine Radiolaria (Class Sarcodina). In, Farinacci, A., ed., *Proceedings II Planktonic Conference, Rome, 1970*, p. 981-992. Tecnoscienza, Rome.
- Riedel, W.R., 1967a: Some new families of Radiolaria. *Proc. Geol. Soc. London*, no. 1640, p. 148-149.
- , 1967b: Protozoa (Subclass Radiolaria). In, Harland, W.B. et al., *The Fossil Record*, p. 291-298. Geol. Soc. London.
- Sashida, K., 1983: Lower Triassic Radiolaria from the Kanto Mountains, Central Japan. Part 1: Palaeoscenediidae. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 131, p. 168-178, pls. 36, 37.
- , 1991: Early Triassic radiolarians from the Ogamata Formation, Kanto Mountains, central Japan. Part 2. *Ibid.*, no. 161, p. 681-696.
- Sato, T., Murata, M. and Yoshida, H., 1986: Triassic to Jurassic radiolarian biostratigraphy in the southern part of Chichibu terrane of Kyushu, Japan. *News of Osaka Micropaleont., Spec. Vol.*, no. 7, p. 9-23. (in Japanese with English abstract)
- Sugiyama, K., 1990: Early to Middle Triassic radiolarian assemblages from Mt. Kinkazan, Gifu City. *Geol. Soc. Japan, Abstracts with Programs, 97th Ann. Meet.*, p. 312. (in Japanese)
- , 1991a: Permian radiolarians from the Triassic distributed in Mt. Kinkazan, Gifu City. *Geol. Soc. Japan, Abstracts with Programs, 98th Ann. Meet.*, p. 148. (in Japanese)
- , 1991b: Early to Middle Triassic radiolarians from Mt. Kinkazan, Gifu Prefecture, central Japan. *Internat. Assoc. Radiolarian Paleontologists, 6th Meet., Firenze, Abstracts*, p.

77.
 —, Nobuhara, T. and Inoue, K., in press: Preliminary report on Pliocene radiolarians from the Nobori Formation, Tonohama Group, Shikoku, Southwest Japan. *Jour. Earth Sci., Nagoya Univ.*, vol. 39.
- Takashima, K and Koike, T., 1982: Triassic radiolarian faunas in chert from some areas in Japan. *Ibid.*, *Spec. Vol.*, no. 5, p. 45-50. (in Japanese)
- Takemura, A., 1986: Classification of Jurassic nassellarians. *Palaeontographica*, Abt. A, vol. 195, p. 29-74.
- Wakita, K., 1988: Origin of chaotically mixed rock bodies in the Early Jurassic to Early Cretaceous sedimentary complex of the Mino terrane, central Japan. *Bull. Geol. Surv. Japan*, vol. 39, no. 11, p. 675-757.
- Yao, A., 1982: Middle Triassic to Early Jurassic Radiolarians from the Inuyama area, central Japan. *Jour. Geosci., Osaka City Univ.*, vol. 25, art. 4, p. 53-70.
- , Matsuda, T. and Isozaki, Y., 1980: Triassic and Jurassic Radiolarians from the Inuyama area, central Japan. *Ibid.*, vol. 23, art. 4, p. 135-154.
- Yeh, K., 1989: Studies of Radiolaria from the Fields Creek Formation, east-central Oregon, U.S.A.. *Bull. Natn. Mus. Nat. Sci., Taiwan*, no. 1, p. 43-109.
- , 1990: Taxonomic studies of Triassic Radiolaria from Busuanga Island, Philippines. *Ibid.*, no. 2, p. 1-63.

Iwato 岩戸, Gifu 岐阜, Mt. Kinkazan 金華山.

岐阜県金華山の下部～中部三畳系より産する放散虫化石：岐阜県岐阜市金華山の珪質岩類より得られた放散虫化石を検討し、3つの放散虫群集を識別した。それらは (1) *Parentactinia nakatsugawaensis* 群集 (Spathian), (2) *Hozmadia gifuensis* sp. nov. 群集 (early Anisian), (3) *Triassocampe coronata* 群集 (middle Anisian) である。放散虫化石を用いた時代決定ならびに堆積学的検討から、調査地域の初生的な層序は暫定的ではあるが、下位から順に下部三畳系の (1) 黒色頁岩, (2) 珪質頁岩～チャート, 及び中部三畳系の (3) 層状チャートと復元された。また本地域から得られた二畳紀放散虫化石について、その産状を論じた。得られた放散虫化石のうち、4新属26新種を含む代表的なものについて記載をおこなった。

杉山和弘

**942. TROPICAL MOLLUSCAN ASSOCIATION IN THE MIDDLE
MIOCENE MARGINAL SEA OF THE JAPANESE ISLANDS:
AN EXAMPLE OF MOLLUSCS FROM THE OYAMA FORMATION,
TSURUOKA CITY, NORTHEAST HONSHU, JAPAN***

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Abstract. The early Middle Miocene molluscs of the Oyama Formation, Yamagata Prefecture, Northeast Honshu, Japan, are considered to have occupied a marginal part of the tropical sea in northern Japan on the basis of biogeographic distribution of molluscan associations including *Geloina*, *Vicarya* and *Leporimetis*. The molluscan fauna is characterized by the occurrence of Arcid-Potamid Fauna and abundant occurrence of Tellinidae (*Macoma*, *Psammacoma*, *Tellina*, *Nitidotellina* and *Leporimetis*) that are deep-burrow detritus feeders. These peculiar occurrences in the Arcid-Potamid Fauna suggest that there were well developed unconsolidated sandy mud bottoms in tidal flats of embayments where each species of the Arcid-Potamid Fauna and tellinid species had been flourished. From a paleozoogeographical point of view, significant difference in faunal association among correlatives with the Oyama Formation can be recognized between those of the areas of modern northwestern Yamagata Prefecture and southern Akita Prefecture, and also between the Kadono area of Joban Coalfield and northward. This difference suggests that there were boundaries of tropical/subtropical marine conditions between these areas in the early Middle Miocene. *Leporimetis takaii* from the Oyama Formation together with other occurrences in Japan are also discussed and described systematically.

Key words. Tropical, Neogene, Miocene, paleozoogeography, Oyama Formation, Yamagata Prefecture

Introduction

Since Ogasawara and Tanai (1952) reported 19 molluscan species of 13 genera from the Miocene Oyama Formation in Yamagata Prefecture, a few additional paleontological and geological studies on the Oyama Formation have been done by Nishida and Chihara (1966), Tsuchiya *et al.* (1984) and Sato *et al.*

(1986). Neogene molluscan studies of the Japanese Islands in the last three decades allow us to consider their paleontological and geological significance from the viewpoints of paleoecology, paleozoogeography and paleoclimatology.

In reference to such increased knowledge, the molluscan association of the Oyama Formation was considered to be the most northern occurrence of tropical water molluscs of the early Middle Miocene in the Japanese

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Islands, mainly based on the geographical distribution of species/genera along the Japanese Islands (Chinzei, 1978, 1986; Ogasawara, 1988). From the zoogeographical and paleoclimatological viewpoints, the genera *Geloina*, *Telescopium*, *Terebralia*, *Ellobium* and *Globularia* are keys to inferring tropical-water conditions within the Yatsuo-Kadonosawa (or Kadonosawa) faunal province in central to northern Japan (Chinzei, 1986; Tsuda *et al.*, 1986).

The *Geloina-Vicarya* association of the Oyama Formation was first reported by Tsuda (1965) and Nishida and Chihara (1966) although they did not describe or illustrate species.

In addition to this molluscan association from the Oyama Formation of Yamagata Prefecture, Hatai (1956) reported *Globularia* (?) *monstrosa* Hatai, which is synonymous with *G. nakamurai*, from the Miocene Takinosawa Formation in Okura-mura, Mogami-gun, Yamagata Prefecture, which is not so far from the locality of the Oyama Formation. Although the *Globularia*-bearing formation and its locality are not well followed by any studies, the genus *Globularia* is a representative of the tropical mangrove swamp fauna (Kobayashi and Horikoshi, 1958; Itoigawa *et al.*, 1981; Taguchi, 1981; Majima, 1989).

On the other hand, typical molluscan associations of the so-called Arcid-Potamid Fauna (Tsuda, 1965; Noda, 1973) which is characterized by such genera and species as *Vicarya*, *Vicaryella*, *Tateiwaia*, *Anadara kakehataensis*, *A. makiyamai*, *Striarca uetsukiensis* and so on, have been found from various localities beyond the northern area of Yamagata Prefecture (Noda, 1973; Chinzei, 1986). Some of the most northern localities yielded *Vicaryella*, one Potamidid mollusc is *V. teshimae* Kanno and Ogawa from the Takinoue Formation in the Yubari district of central Hokkaido (Kanno and Ogawa, 1964) and the Furanui Formation, western part of the Hidaka Mountains (Uchimura, 1991).

However, fossil localities in the more northern parts of the Oyama Formation recorded no *Geloina* species and also no tropical molluscan genera such as *Terebralia*, *Globularia*, *Telescopium* and *Ellobium*.

Consequently, the geographic distribution of the characteristic genera and species of the Yatsuo-Kadonosawa Fauna in Japan suggests that the present locality of Yamagata Prefecture corresponds to the Middle Miocene tropical front area from a paleozoogeographical viewpoint.

In the present paper, we mainly deal with the molluscs newly collected from the Oyama Formation during a field survey in Tsuruoka City in 1990. In addition to this collection, we report here some molluscs stored in Yamagata Prefectural Museum which were collected from the Oyama Formation at Shimoshimizu and Oyama Park in 1969 by Mr. Tamiya and others.

All of the specimens in the present work are deposited in Yamagata Prefectural Museum of Yamagata City.

Geological setting

The Tertiary strata developed in the southwestern area in Tsuruoka City, Yamagata Prefecture are restricted to Lower to Middle Miocene and it covers unconformably the pre-Tertiary granitic rocks. It is divided into the Irakawa, Zempoji, and Oyama Formations, in ascending order (Tsuchiya *et al.*, 1984) (Figure 1).

The Irakawa Formation, which is the lowest stratigraphic unit of the Tertiary in the area, is composed of felsic and andesitic pyroclastics, andesitic lava flows, sandstone and siltstone intercalated with conglomerate and carbonaceous layers. The Irakawa Formation is a terrestrial deposit and yielded the Aniai-type Flora (Tanai, 1951).

The Zempoji Formation unconformably overlies the Irakawa Formation and is composed of conglomerate, andesitic lava, felsic

Stratigraphic division	Lithology & Fossils
Kusanagi Formation (100-400 m)	hard siltstone intercalated with sandstone and felsic tuff
Oyama Formation (200-450 m)	felsic-andesitic tuff, tuffaceous sandstone, mudstone and conglomerate Mollusca, Foraminifera
Zempoji Formation (200-500)	felsic-andesitic tuff, tuffaceous sandstone and mudstone andesitic lava, conglomerate Daijima-type Flora
Irakawa Formation (300 m+)	conglomerate, sandstone and mudstone with carbonaceous mudstone andesitic lava, felsic pyroclastics Aniai-type Flora
Unconformity	
Pre-Tertiary Granitic rocks	

Figure 1. Lower to Middle Miocene stratigraphic divisions of the studied area (after Tsuchiya *et al.*, 1984)

and andesitic tuffaceous sandstone and mudstone. This formation yielded many plant fossils belonging to the Daijima-type Flora (Tanai, 1951; Sato *et al.*, 1986). The Zempoji Formation is intruded by the Shorenji Dolerite which is rather widely distributed in the southwestern part of Tsuruoka City. This dolerite is considered to have been intruded at the time of deposition of the Oyama Formation (Tsuchiya *et al.*, 1984).

The Oyama Formation is mainly composed of conglomerate, alternation of tuffaceous sandstone and siltstone, massive siltstone, felsic lapilli tuff and tuffaceous sandstone, and alternating sandstone and siltstone. It attains about 300 m in thickness. This formation yielded not only molluscs but also silicified wood and many plant fossils. Molluscs occurred as molds and casts. The Oyama Formation is conformably overlain by the Kusanagi Formation which is mainly composed of hard siliceous siltstone.

Occurrence of molluscs

Three molluscan fossil localities of the Oyama Formation in the present report are

Sakashita, Shimoshimizu and Oyama Park (Figure. 2). Among these, the Oyama Park locality is the same as the locality of Tsuchiya *et al.* (1984). However, the other localities are different from the previously reported ones by Ogasawara and Tanai (1952) and Nishida and Chihara (1966). These fossil localities are correlatable with the middle to upper part of the Oyama Formation.

All molluscs of the present report occurred as inner and outer molds or casts but the delicate surface sculpture is rather well preserved. Almost all the bivalve molluscs such as *Anadara kakehataensis*, *Diplodonta ferruginata*, *Cycladicama cf. takeyamai*, *Cyclina japonica*, *Clementia papyracea*, *Leporimetis takaii* and *Hiatula minoensis* occur as conjoined valves. Such molluscan occurrences in the Oyama Formation suggest, in general, that the molluscs are autochthonous.

The exposure at Sakashita is composed of alternating tuffaceous sandstone and siltstone (16 m thick), mollusca-bearing massive gray siltstone (22 m thick), alternation of tuffaceous sandstone and siltstone (10 m thick), *Vicarya-Anadara*-bearing tuffaceous silty sandstone (14 m thick) and tuffaceous

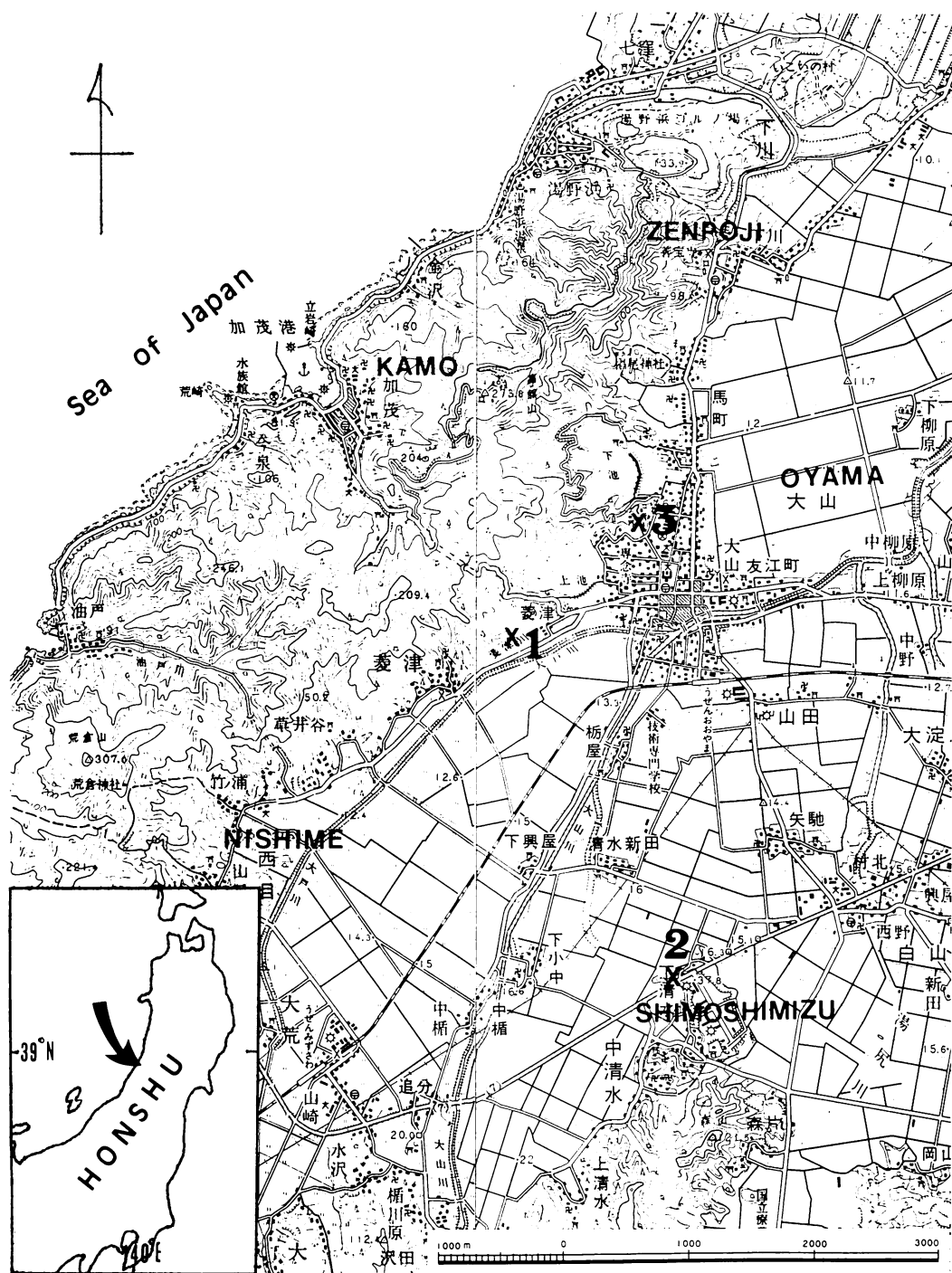


Figure 2. Fossil locality map (Adapted from Geographical Quadrangle Map “Sanze” and “Tsuruoka,” scale 1 : 50,000, Agency of Land and Survey, Ministry of Construction)

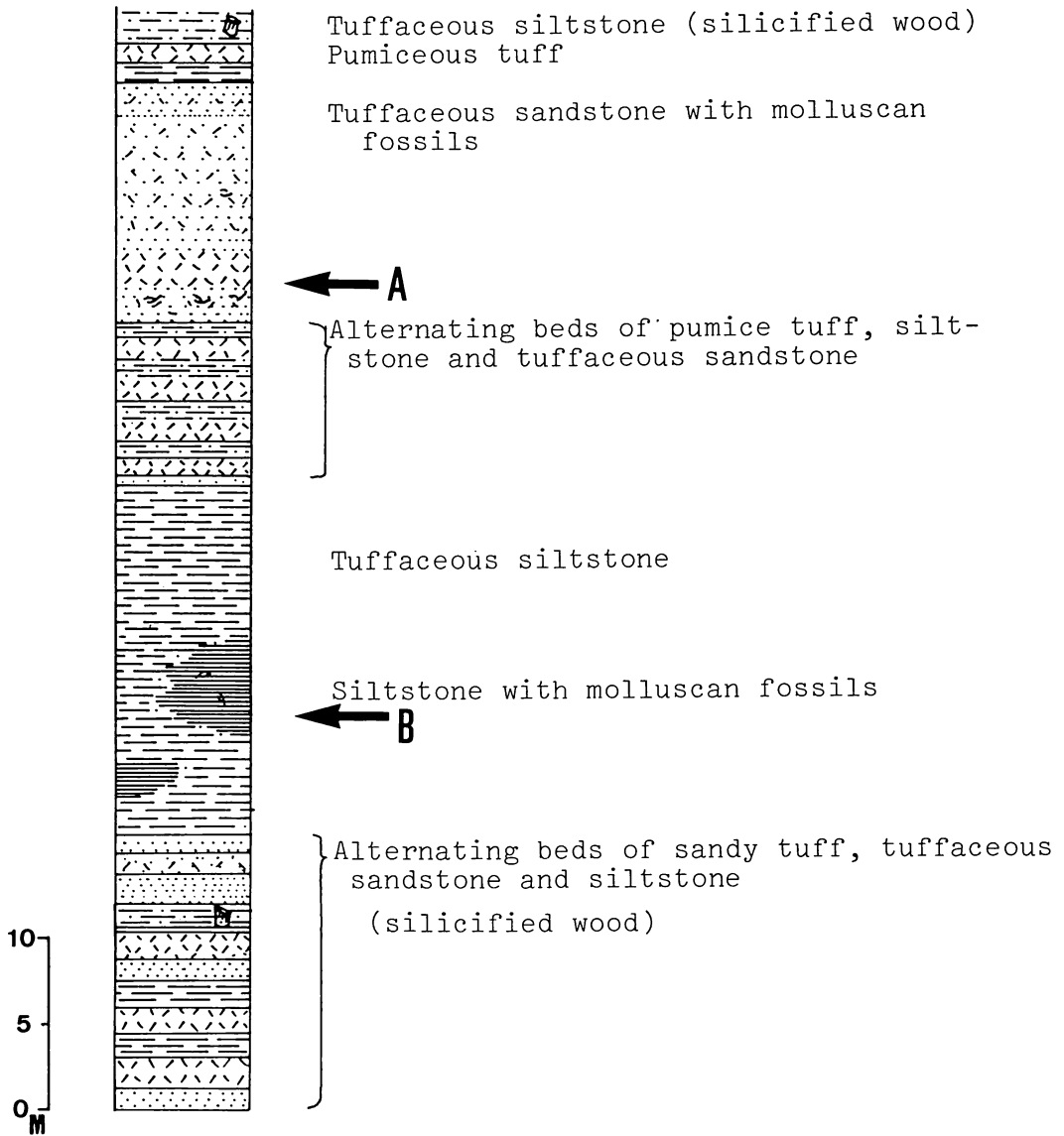


Figure 3. Geologic column at Sakashita showing the fossil-bearing horizons of the Oyama Formation

siltstone intercalated with fine tuff (4 m thick), in ascending order (Figure 3). This section is correlated to the middle to upper part of the Oyama Formation. It is interesting that abundant conjoined valves of *Cycladicama*, *Diplodonta* and *Leporimetis* species occurred from a siltstone of the lower part (Horizon B), while abundant conjoined valves of *Anadara kakehataensis* and *Le-*

porimetis takaii associated with *Vicarya yokoyamai* were collected from a silty sandstone of the upper part (Horizon A).

At Shimoshimizu, in a road cut on National road Route No. 7, weakly stratified silty sandstone and mollusc-rich sandy siltstone about 10 m in total thickness are exposed. Among the molluscs sporadically occurring from the top of this cutting,

bivalves are mostly conjoined. This locality is the uppermost horizon of the present three localities.

The third locality is a small cliff in the southeastern part of the Shimoike Pond in the Oyama Park. Molluscs from this locality were collected in 1969 by Tamiya *et al.* The lithofacies of the locality is characterized by ill-sorted silty sandstone irregularly containing granular conglomerate. In this locality, conjoined bivalves of *Anadara kakehataensis* and *Diplodonta ferruginata* are dominant in association with conjoined bivalves of *Leporimetis* and *Clementia*. The association is very similar to those of the other two localities in specific composition.

Molluscan associations

As shown in Table 1, 30 molluscan species from the three localities in the Oyama Formation have been identified. Among these, *Anadara kakehataensis*, *Diplodonta ferruginata*, *Cycladicama* cf. *takeyamai*, *Cyclina japonica*, *Leporimetis takaii* and *Hiatula minoensis* are dominant. It is interesting that *Leporimetis takaii* occurs in all of the localities although the lithofacies and molluscan associations slightly differ in each. Moreover, *Leporimetis takaii* and its associations are most characteristic in comparison with other localities that have yielded the Kadonosawa Fauna in Japan. The other molluscan species, except for some tellinid bivalves, are very similar to those of the Arcid-Potamid Fauna of the Kadonosawa faunal association (Chinzei and Iwasaki, 1967; Chinzei, 1981, 1986; Itoigawa *et al.*, 1981, 1982; Taguchi, 1986).

Unfortunately, a few genera such as *Geloina*, *Striarca* and tellinids that were previously reported from the Oyama Formation (Ogasawara and Tanai, 1952; Nishida and Chihara, 1966) were not collected in the present study. However, the most characteristic species are included in the present collections. Moreover, it can be said that the

molluscan associations of each locality are very similar to each other.

Consequently, a total of 30 genera and 40 species are identified from the Oyama Formation including the species reported previously. Among these, *Leporimetis takaii* (including *L. nipponica* (Oyama MS) as a synonym), *Nitidotellina kagayamaensis*, *Cultellus otukai* and *C. oyamaensis* were previously described from the Oyama Formation by Ogasawara and Tanai (1952).

Age and correlation

Anadara kakehataensis, *Leporimetis takaii*, *Hiatula minoensis*, *Vicarya yokoyamai* and *Cerithideopsisilla yatsuoensis* are very significant for age determination and paleoenvironmental reconstruction of the Oyama Formation.

Leporimetis takaii is considered to be a peculiar species within the Kadonosawa Fauna. This species is known from the Kurosedani Formation of Toyama Prefecture (Oyama, 1950), Yoshino Formation of Katsuta Group, Okayama Prefecture (Taguchi, 1981), Sunakozaka Formation of Ishikawa-Toyama Prefectures (Sasaki and Ogasawara, 1986), Kunimi Formation of Fukui Prefecture (Nakagawa, 1989) and Tamagawa Formation of Ibaraki Prefecture (Noda *et al.*, 1989).

Molluscan associations containing *Vicarya yokoyamai* are very comparable with those of the Kadonosawa Fauna of the early Middle Miocene in Japan.

According to the biochronological compilation of Saito *et al.* (1986) and Oda (1986), the Kadonosawa Fauna can be assigned an age range of 16.5 to 15 Ma, however the oldest Neogene *Vicarya* species is known from the Kunugidaira Formation of Joban coalfield on Honshu Island (Kamada, 1962; Takahashi, 1984), is of Early Miocene age (19 Ma) (Ogasawara, 1988).

The Oyama Formation is also correlatable to those of *Globularia*-bearing formation re-

Table 1. Molluscan fossils from the Oyama Formation, Yamagata Prefecture

Species	Locality numbers			
	1B	1A	2	3
<i>Anadara (Hataiarca) kakehataensis</i> Hatai and Nishiyama		VA	F	VA
<i>Anadara</i> sp.	F			
<i>Solamen</i> cf. <i>fornicatum</i> (Yokoyama)			F	F
<i>Crassostrea gravitesta</i> (Yokoyama)				R
" <i>Ostrea</i> " sp.		R		
<i>Diplodonta ferruginata</i> Makiyama	VA			A
<i>Cycladicama</i> cf. <i>takeyamai</i> (Otuka)	VA			
<i>Cycladicama</i> sp.	C			
<i>Vasticardium ogurai</i> (Otuka)			F	
<i>Cardilia toyamaensis</i> Tsuda			F	
<i>Cyclina japonica</i> Kamada		VA		F
<i>Clementia papyracea</i> (Gray)		C	C	F
<i>Paphia</i> cf. <i>ohiroi</i> Masuda	F		C	
<i>Leporimetis takaii</i> (Ogasawara and Tanai)	A	A	C	A
<i>Macoma</i> aff. <i>praetexta</i> (v. Martens)			C	
<i>Macoma</i> sp.	F		F	
<i>Tellina</i> cf. <i>notoensis</i> Masuda			C	
<i>Tellina</i> cf. <i>osafunei</i> Taguchi			F	
<i>Nitidotellina kagayamensis</i> (Ogasawara and Tanai)	R			
<i>Psammacoma</i> aff. <i>awajiensis</i> (Sowerby)			F	
<i>Hiatula minoensis</i> (Yokoyama)		VA		F
<i>Cultellus izumoensis</i> Yokoyama			C	
<i>Cultellus</i> sp.	R			
<i>Teredo</i> sp.			F	
<i>Vicarya yokoyamai</i> Takeyama	R	F		R
<i>Cerithideopsilla yatsuoensis</i> Tsuda	F			
<i>Cerithidea</i> sp.	R			
<i>Chicoreus</i> cf. <i>tiganouranus</i> (Nomura)	F		F	F
" <i>Cirsotrempsis</i> " sp.	F			
" <i>Natica</i> " sp.			F	

VA : more than 20 individuals, A : 19-10 individ., C : 9-5 individ., F : 4-2 individ., R : 1 individ.

Locs. 1B, 1A : Sakashita, Oyama-machi, Tsuruoka City. B. Lower horizon, A. Upper horizon.

Loc. 2 : Shimoshimizu, Turuoka City

Loc. 3 : Oyama Park, Oyama-machi, Tsuruoka City

ported by Hatai (1956) in terms of Miocene climatic succession as it is assignable to tropical marine conditions.

The Oyama molluscan association is very allied to those of the Kakehata and Doh association of the Kurosedani Formation

(Hatai and Nishiyama, 1949 : Oyama, 1950 ; Tsuda, 1959, 1960), Ajiri and Shiogama Formations of Miyagi Prefecture (Nomura, 1935), and also Kadonosawa Formation of Iwate Prefecture (Otuka, 1934). It is also very similar to those of the Okushiri Formation (Tsuiri-

ake Fauna; Uozumi and Fujie, 1966), Kun-nui Formation (Kanno, Amano and Noda, 1988) and lower part of the Sugota Formation of Akita Prefecture (Ozawa *et al.*, 1979; Sasaki, 1991).

Paleoenvironment

The present molluscan collection from the Oyama Formation is insufficient for a detailed discussion of the depositional paleoenvironments of the Oyama Formation, but we focus on the zoogeographical significance of the dominant molluscan species and its association.

As compared with those of the Kadonosawa Fauna, the most characteristic features of the Oyama Fauna is abundant co-occurrence with elements of the Arcid-Potamid Fauna together with *Leporimetis takaii*. Some modern specimens of *Leporimetis spectabilis* and its allied species are known from tropical seas as far south as Okinawa, where they live on fine sandy bottoms at littoral to very shallow water depths (Habe, 1977). By analogy, *Leporimetis takaii* can be considered a tropical species.

According to Taguchi (1981), who reconstructed the brackish interspecific association of the Kadonosawa Fauna as exemplified by the Bihoku Group in Southwestern Japan, the *Vicarya-Geloina* Association included no *Leporimetis* species; however, he reported *Apolymetis* sp. from the Bihoku Group. However, *Leporimetis* species are known from some localities in the Japanese Islands although not to the degree to which they occur in comparison with that of the Oyama Formation. This difference probably resulted from bottom conditions, whether well consolidated or not, because *Leporimetis* is a representative detritus feeder or deep burrower. Its peculiar external shape of ridge and depression at central portion on shell suggests some suitable adaptation for maintaining a life position in such unconsolidated muddy sand bottoms. In addition,

occurrence of many tellinid species in association with *Leporimetis takaii* also suggests that soft muddy bottoms were well developed at the time of deposition of the Oyama Formation.

The Arcid-Potamid Fauna of the Kadonosawa Fauna is considered to have flourished in brackish embaymental to lagoonal environments as many molluscan paleontologists have discussed (Tsuda, 1965; Noda, 1973; Chinzei, 1978 and others). Specific association of the Oyama Formation suggests an environment similar to that cited above, combined with rare occurrence of *Cerithideoposilla yatsuoensis*. Based on the pattern of conjoined occurrence of the specimens and species associations, the Oyama Fauna suggests a principal environment in unconsolidated muddy bottoms in brackish to open shallow seas. As Chinzei discussed, *Crassostrea* may be specially adapted to live in and on mud bottoms as they have chalky-structured shell (Chinzei, 1982a-b). On the other hand, *Leporimetis* may have adapted to life in unconsolidated muddy bottoms by the depressed portion of its shell surface. Undiscovered and/or very rare occurrence of *Crassostrea* from the Oyama Formation is explained by such environmental differences as cited above.

From a paleo-marine climatological point of view, *Geloina-Vicarya* and associated species indicate tropical-water conditions. *Geloina* and other mangrove species such as *Globularia*, *Terebralia* and *Telescopium* have not been recorded in any strata north of the present Oyama Formation in the northwestern part of Yamagata Prefecture.

For instance, from the Dewa Hill area of Akita Prefecture, the lower part of the Sugota Formation yields *Batillaria* sp., *Vicaryella notoensis*, *Anadara* sp. and *Crassostrea gravitesta* (Sasaki, 1991) but *Vicarya*, *Geloina* and *Leporimetis* have not been discovered.

Distorsio kotakai, one of the tropical to subtropical species, was described from the Yanagawa Formation, Fukushima Prefecture

together with many warm-water species, but it was considered as subtropical based on molluscan associations (Ogasawara and Morita, 1990).

From the Tamagawa Formation in Ibaraki Prefecture, a *Vicarya-Anadara kakehataensis*-bearing molluscan fauna was reported

by Noda *et al.* (1989). However, *Geloina* and other typical mangrove species were not discovered. However, *Terebralia* sp. which is assignable to one of the representative genera of the tropical mangrove swamp fauna, was reported together with many constituent species of the Arcid-Potamid Fauna from the Nakayama Formation distributed in the Kadono district of Joban Coalfield by Takahashi (1984). This Nakayama Fauna of the Joban Coalfield should be considered as tropical following studies concerning the mangrove swamp fauna (Taguchi, 1981; Tsuda *et al.*, 1986; Itoigawa and Tsuda, 1986).

Therefore, it can be concluded that the tropical-sea front and/or tropical mangrove front should be put at the following two areas: the Oyama Formation in Yamagata Prefecture and the Nakayama Formation in the Kadono district, Fukushima Prefecture. All localities which yielded the Kadonosawa Fauna in northern Japan are shown in Figure 4. Among these, some localities have no records of tropical mangrove species although they occurred south of Tsuruoka in Yamagata Prefecture and the Kadono district of Fukushima Prefecture such as the Tamagawa Formation (No. 61; Noda *et al.*, 1989) and the Kozono Formation in Saitama Prefecture (No. 62; Majima and Takahashi, 1987; Majima, 1989). This should be interpreted at present as due to insufficient collection of molluscs or lack of exposures.

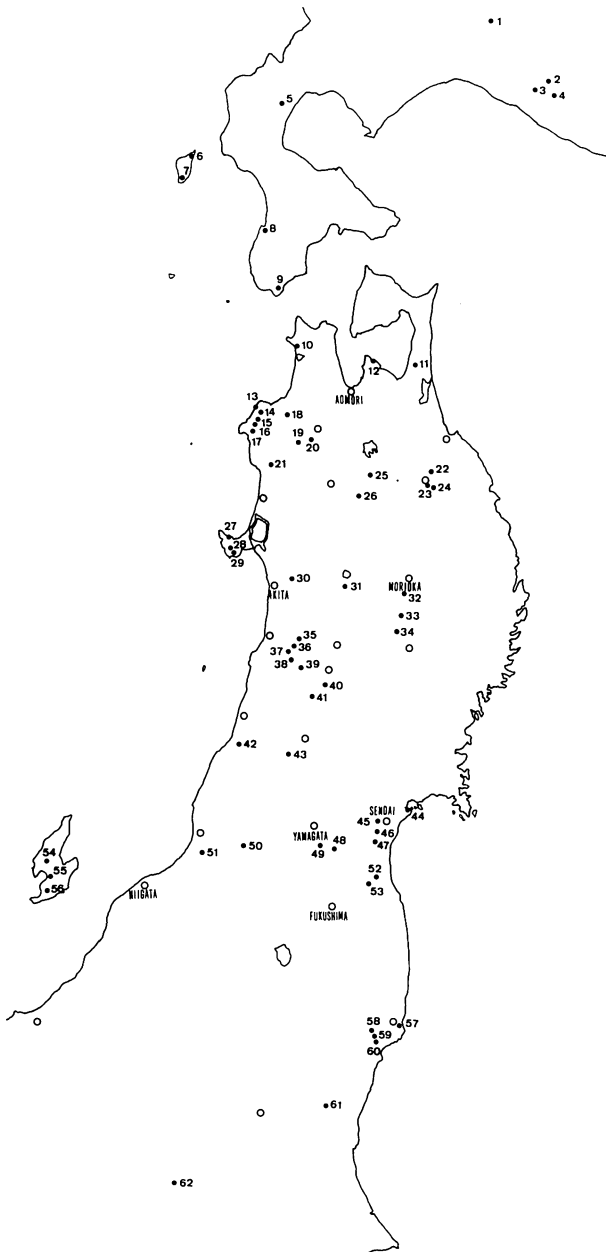


Figure 4. Fossil localities to be correlated to that of the Oyama Formation in northern Japan.

1. Takinoue, 2-4. Furanui, 5. Kunnui, 6-7. Tsurikake, 8. Ohanzai, 9. Yoshioka, 10. Isomatsu & Fuyube, 11. Takahoko, 12. Benkeinai, 13-17. Tanosawa, 18. Tanosawa (Takibuchi-damsite), 19-20. Sunakose, 21. Kuroishizawa, 22-24. Kadonosawa, 25. Oinosawa, 26. Hanawa, 27-29. Nishikurosawa, 30. Sunakobuchi, 31. Mikaeritoge, 32-34. Iioka, 35-40. Sugota, 41. Shunzaka, 42. Oyama, 43. Okura-mura, 44. Shiogama & Ajiri, 45. Moniwa, 46. Hashimoto, 47. Tsukinoki, 48-49. Zaoh, 50. Myozawabashi, 51. Kamagui, 52. Kozai, 53. Yanagawa, 54-56. Orito, 57. Taira, 58-60. Nakayama (Kadono), 61. Tamagawa, 62. Kozono.

Paleogeography and shallow marine zoogeographic divisions at the time the Kadonosawa Fauna flourished (about 16 Ma) are shown in Figure 5. This paleogeographic map is modified on the basis of Chiji and IGCP-246 National Working Group of Japan (1988) and Hayashida and Torii (1988), which was proposed from the viewpoint of paleomagnetic studies of southwestern Japan.

Concerning the geographic distribution of one element of the Arcid-Potamid Fauna, it is notable that the geographical distribution of *Striarca uetsukiensis* extends farther north than Chinzei considered (1986). Because the species is known from the Okushiri, Kunnui and Kadonosawa Formations in northern Japan, it is considered that *Striarca uetsukiensis* occurs both in tropical and subtropical seas.

Description of characteristic molluscan species of the Oyama Formation

Phylum Mollusca

Class Bivalvia

Family Arcidae Lamarck, 1809

Genus *Anadara* Gray, 1847

Subgenus *Hataiarca* Noda, 1966

Anadara (Hataiarca) kakehataensis

Hatai and Nisiyama

Figures 7-18,—20a-c.

Anadara kakehataensis Hatai and Nisiyama, 1949, p. 88, pl. 23, figs. 8-10.

Anadara (Hataiarca) kakehataensis Hatai and Nisiyama. Noda, 1966, p. 116, pl. 2, fig. 17, pl. 13, figs. 7, 8, 10-15, 21; Noda, 1973, pl. 18, figs. 1-16; Taguchi, 1981, pl. 2, figs. 1-5; Sasaki and Ogasawara, 1986, pl. 5, figs. 1a-b, 4a-b; Noda and Takahashi, 1986, pl. 5, figs. 1-11; Kanno, Amano and Noda, 1988, p. 379-380, pl. 1, figs. 1-2; Nakagawa, 1989, pl. 1, fig. 1.

Anadara (Hataiarca) cf. kakehataensis Hatai and Nisiyama. Takahashi, 1984, pl. 1, fig. 1.

Measurements (in mm)

Coll. no.	Valve	Length	Height	Depth	No. of rib	Remarks
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SS-1	left	47.40	35.01	ca.14.4	28	
-2	right	42.60	34.01	ca. 8.4	28	deformed
-3	left	47.40+	ca.38	ca.15.5	25+	
-4	left	45.15	38.70	17.6	25+	conjoined
-5	right	45.60	34.40	13.4	28	
-6	left	ca.35	ca.28	—	—	
-7	right	23.60	18.30	5.0	25+	
-8	right	44.30	—	—	25+	conjoined

Remarks.—This species resembles *Anadara daitokudoensis* Makiyama, but is discriminated from the latter by a well inflated and high shell with about 26 radial ribs. The localities of *Anadara kakehataensis* were shown by Noda and Takahashi (1986).

This species is one of the representative species of the Arcid-Potamid Fauna of Tsuda (1965), and is a brackish inner embaymental tidal to very shallow water species as pointed out by Noda and Takahashi (1986).

Geologic records.—Kunnui and Tsurikake Formations in Hokkaido, Tanosawa and Maenokawa Formations of Aomori Prefecture, Kadonosawa Formation of Iwate Prefecture, Ajiri and Tsukinoki Formations of Miyagi Prefecture, Meganebashi Formation of Yamagata Prefecture, Iwafune and Orito Formations of Niigata Prefecture, Kurosedani and Sunakozaka Formations of Toyama Prefecture, Higashiinnai, Sunakozaka and Kawaminami Formations of Ishikawa Prefecture, Kunimi Formation of Fukui Prefecture, Katsuta and Yoshino Formations of the Bihoku Group of Chugoku district, Nakayama Formation of Fukushima Prefecture, Asakawa and Tamagawa Formations of Ibaraki Prefecture, and Eoil Formation of Korea.

Family Ungulinidae H. and A. Adams, 1857

Genus *Diplodonta* Bronn, 1831

Diplodonta ferruginata Makiyama

Figures 7-6a-c,—7a-c,—8.

Diplodonta ferruginata Makiyama, 1926, p. 157-158, pl. 12, figs. 12, 13; Uozumi and Fujie, 1966, p. 150, pl. 12, figs. 8, 9; Itoigawa in Itoigawa *et al.*,

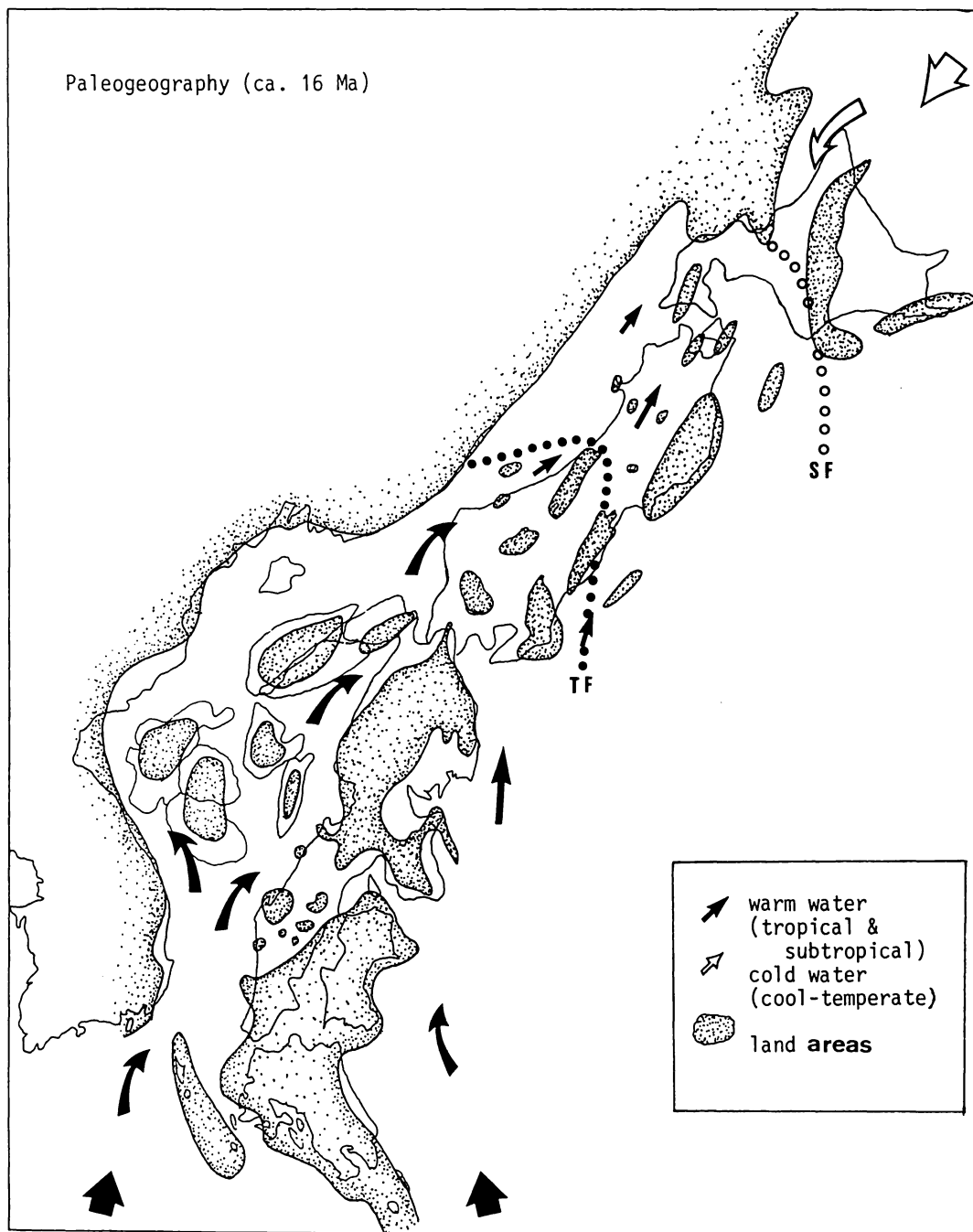


Figure 5. Paleogeography and shallow marine zoogeographic divisions of the Kadonosawa Fauna at about 16 Ma, showing the tropical front and/or mangrove swamp faunal front (TP) and subtropical front (SF).

1974, p. 76, pl. 19, figs. 5a-c; Itoigawa *et al.*, 1981-1982, p. 70, pl. 12, figs. 8a-b, 11a-b; Nakagawa and Takeyama, 1985, pl. 17, fig. 1; Ozawa *et al.*, 1986, pl. 14, fig. 10.

Taras ferruginata (Makiyama). Otuka, 1934, p. 616, pl. 45, figs. 29, 40.

Felaniella ferruginata (Makiyama). Sasaki and Ogasawara, 1986, pl. 5, fig. 10; Nakagawa, 1989, p. 37, pl. 1, fig. 9.

Measurements (in mm)

Coll. no.	Valve	Length	Height	H/L	Depth	D/L	Remarks
SK-1	right	21.70	20.00	0.92	10.4/2	0.24	not deformed
-2	right	22.60	18.50	0.82	12.0/2	0.27	weak. compressed
-3	right	19.40	20.60	1.06	10.4/2	0.27	deformed
-4	left	21.70	20.10	0.93	—	—	deformed
-5	left	24.00	21.40	0.89	6.0	0.25	
-6	right	20.00	18.50	0.93	6.2	0.31	deformed

Remarks.—According to the original description, the holotype was measured as 18.0 mm in length, 15.5 mm in height and 5.4 mm in depth. The form ratios of the holotype are 0.86 in Height/Length and 0.3 in Depth/Length. Measurements of specimens from the Oyama Formation are shown above, and it is considered that the Oyama specimens are an intraspecific variation of *D. ferruginata*, although they are more or less deformed. The species bears no lunule and no escutcheon with pointed beak.

As workers have differed on the generic placement of this species, including it also in *Felaniella* and *Diplodonta*, the presence of escutcheon and external ligament are a good key for identification. The Oyama specimens belong to *Diplodonta* mainly based on the lack of escutcheon.

Genus *Cycladicama* Valenciennes, 1854

Cycladicama cf. takeyamai (Otuka)

Figures 7-1,—3; 9-8,—9.

Compared with; *Joanisiella takeyamai* Otuka, 1938, p. 29, pl. 4, figs. 32-34, 37.

Measurements (in mm)

Coll. no.	Valve	Length	Height	Depth	H/L	D/L	Remarks
00-1	left	26.30	21.00	6.0	0.8	0.23	typical form
00-2	right	21.30	18.10	5.85	0.85	0.27	typical form
00-3	right	27.80	19.00	11.0	0.68	0.4	elongated
00-4	right	25.30	20.70	—	0.82	—	beak missed
00-5	right	16.70	15.20	8/2	0.91	0.24	conj. small type
00-6	right	25.55	18.50	13.2/2	0.72	0.26	elongated
00-7	left	24.20	21.00	13.6/2	0.87	0.28	conjoined
00-8	left	24.40	19.10	—	0.78	—	depressed

Remarks.—The genus *Joanisiella* Dall, 1895 is considered to be preoccupied by *Cycladicama* Valenciennes, 1884 as noted by Habe (1977). According to original measurements, the Height/Length and Depth/Length ratios vary from 0.79 to 0.96 and 0.28 to 0.4, respectively. The specimens from the Oyama Formation are most allied to *C. takeyamai* but are large in size and less inflated compared with the type specimen. *Cycladicama meisensis* (Makiyama) is very close to the present species but the former differs from the latter in having a well developed umbonal area.

Family Veneridae Rafinesque, 1815

Genus *Clementia* Gray, 1842

Clementia papyracea (Gray)

Figures 7-11a-b, —12,—13; 9-22, —30.

Clementia papyracea (Gray). Ogasawara and Tanai, 1952, p. 208, pl. 19, figs. 4, 5; Shuto, 1960, p. 140, pl. 13, figs. 8, 11, text-figs. 5, 6, 9; Itoigawa in Itoigawa, Shibata and Nishimoto, 1974, p. 93, pl. 27, figs. 6a-b.

Clementia japonica Masuda, 1955, p. 121, pl. 19, fig. 8; Masuda, 1966, pl. 35, fig. 30.

Measurements (in mm)

Loc. Shimoshimizu

Coll. no.	Valve	Length	Height	Depth	H/L	D/L	Remarks
SS-1	right	ca.49.0	46.10	20.0/2	0.94	0.20	not deformed
-2	right	44.10	43.00	24.0/2	0.98	0.27	elongated
-3	right	32.40	37.60	18.6/2	1.16	0.29	elongated
-4	right	34.2+	31.70	13.4/2	—	—	poster. miss.
-5	left	33.50	30.50	—	0.91	—	deformed
-6	right	28.00	20.30	9.0	0.76	0.32	deformed

Remarks.—This species may have flourished on the muddy bottom of a shallow warm-water sea. *Clementia japonica* described by Masuda from the Higashi-Innai Formation is characterized by transversely elongated shell (34 mm height, 44 mm length and 13 mm depth; H/L=0.77; D/L=0.30), but it is considered to be an intraspecific variation of the present species. The specimens from the Oyama Formation can not be discriminated from the modern species *C. papyracea* by its shell outline.

Family Tellinidae de Blainville, 1814

Genus *Leporimetis* Iredale, 1930

Leporimetis takaii (Ogasawara and Tanai)

Figures 8-3,—4,—14; 9-21,—23,—25,—26.

Apolymetis (Leporimetis) takaii Ogasawara and Tanai, 1952, p. 209, pl. 19, fig. 11.

Apolymetis (Leporimetis) nipponica Oyama (MS), Ogasawara and Tanai, 1952, p. 209, pl. 19, figs. 10a-b; Sasaki and Ogasawara, 1986, pl. 6, fig. 20.

Apolymetis sp., Taguchi, 1981, pl. 3, fig. 2.

Description.—Shell moderate, subtrigonal to subquadrate, equivalve, inequilateral, and moderately inflated with twisted posterior end. Beak prominent and incurved. Umbonal area roundly elevated. Anterior dorsal margin long, slightly arched and connected with widely rounded margin. Posterior dorsal margin short, weakly arched and descending into slightly truncated its margin. Well-marked ridge and hollow running from beak to posterior end, which is twisted. Surface sculptured with distinct and rather loose concentric striae. Ligament moderate and narrow but distinctly marked. Lunule wide and large. Two cardinal teeth distinct but small. Other inner structures unknown.

YM no.	Valve	Length	Height	Depth	H/L	D/L	Remarks
1	right	24.05	17.00	10.8/2	0.71	0.22	conjoined
2	right	32.20	24.90	—	0.77	—	conjoined
3	right	34.20	28.20	—	0.82	—	
4	right	43.80	34.80	9.8	0.79	0.22	

5	left	38.50	32.85	10.04	0.85	0.26	not deform.
6	right	39.30	28.25	6.6	0.72	0.17	elongated
7	right	41.40	29.00	9.3	0.70	0.22	deformed
8	right	36+	31.45	—	—	—	conjoined
9	right	31.45	26.55	13.00/2	0.84	0.21	conjoined
10	left	34.60	26+	—	—	—	deformed
11	right	32.20	21.40	—	0.66	—	
12	right	36.30	24.55	7.5/2	0.68	0.10	compressed
13	right	30.0	22.45+	12/2	—	—	deformed
14	right	34.75	25.10	12/2	0.72	0.17	depressed
15	right	28.60	24.50	6.3/2	0.86	—	depressed
16	right	30.90	21.0+	10.0/2	—	0.16	deformed
17	left	42.20	29.80	6.7	0.71	0.16	typical form
18	left	36.60	31.15	13.85/5	0.85	0.19	typical form
19	left	37.80	31.00	16.0/2	0.82	0.21	ceformed
20	left	36+	31.4	—	—	—	

Loc. Sakashita (lower part)

i	right	31.80	22.65	8.6	0.71	0.27	
ii	right	32.60	23.00	—	0.71	—	
iii	right	39.50	26.10	13.6/2	0.66	0.17	ventral miss.
iv	right	22.00	20.80	—	0.95	—	high-type
v	right	32.0	23.4	6.8/2	0.73	0.11	compressed
vi	right	23.60	18.4	—	0.78	—	deformed
vii	right	30.0	22.4+	7.0/2	—	0.12	compressed

Loc. Sakashita (upper part)

A	left	38.25	29.30	—	0.77	—	
B	right	39.15	26.60	—	0.68	—	
C	right	30.80	24.95	6.4	0.81	0.21	
D	right	36.50	30.80	16.0/2	0.84	0.22	conjoined
E	right	31+	—	—	—	—	
F	right	39.0	—	13.4/2	—	0.17	conjoined
G	right	31.5+	—	9.4/2	—	—	conjoined
H	right	35.85	28.10	13.9/2	0.78	0.19	typical form
I	right	39.25	30.75	8.8	0.78	0.22	typical form
J	left	39.20	—	—	—	—	broken
K	left	33.50	30.20	19.3/2	0.90	0.29	very inflated
L	left	36.10	30.20	12.4/2	0.84	0.17	conjoined
M	left	27.20	20ca.	—	—	—	deformed
N	left	26.80	—	—	—	—	deformed
O	right	23.20	17.70	4.5	0.76	0.19	

Loc. Oyama Park

a	right	39.70	31.00	—	0.78	—	
b	right	32.60	29.60	18.85/2	0.91	0.29	conjoined
c	right	36.00	27.80	12.2/2	0.77	0.17	conjoined
d	right	27.25	19.2+	—	—	—	conjoined
e	right	23.10	17.55	—	0.76	—	

Remarks.—This species is characterized by the ridge running from near beak to posterior end, slightly twisted posterior end and

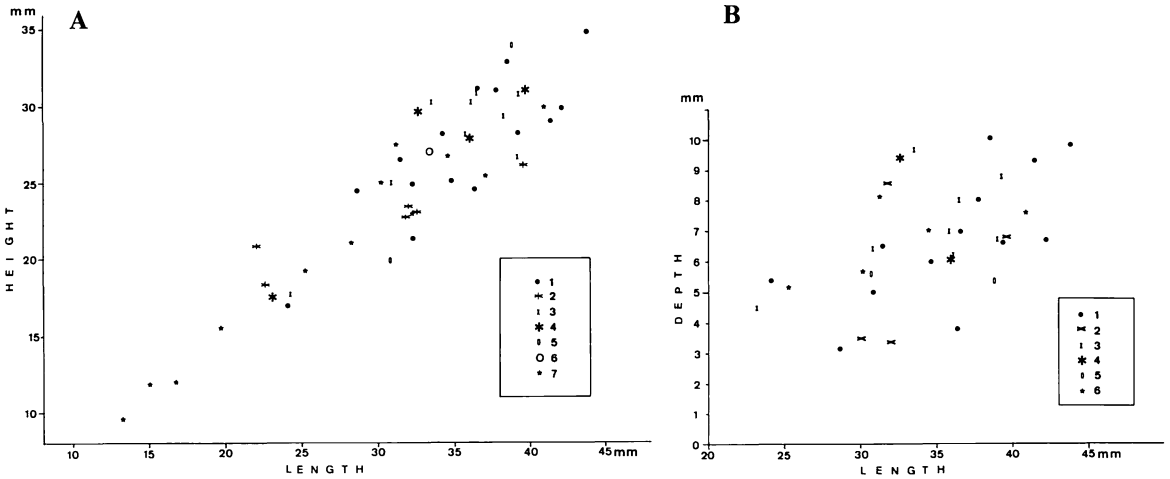


Figure 6. Relationship between Length and Height (A), and Length and Depth (B) of *Leporimetis takaii* Ogasawara and Tanai from various localities. 1: Shimoshimizu, Oyama Formation, 2: Lower horizon (B) of Sakashita, Oyama Formation, 3: Upper horizon (A) of Sakashita, Oyama Formation, 4: Oyama Park, Oyama Formation, 5: Kakehata, Kurosedani Formation, Toyama Prefecture, 6: Sunakozaka Formation, Ishikawa Prefecture, 7: Tohno, Tamagawa Formation, Ibaraki Prefecture.

distinct fine concentric striae on the shell surface. The shell with its twisted posterior end and two small cardinals without lateral tooth is identical to the genus *Leporimetis* Iredale, 1930 (type species: *Tellina spectabilis* Hanley) although the genus is very close to the genera *Hemimetis*, *Tellinimactra* and *Psammotreta* in outline. The genera *Apolymetis* and *Florimetis* are synonyms of *Leporimetis* in the opinion of Coan (1971) and Habe (1977).

Apolymetis nipponica Oyama (MS) illustrated and discussed by Ogasawara and Tanai (1952) is an invalid name because it was only illustrated, not described. Moreover, *A. nipponica* is considered to be an intraspecific variation of *A. takaii*, described in the same paper. Although Ogasawara and Tanai (1952) described the shell inflation in both species as different, the Height/Length and Depth/Length ratios show a gradual change within those specimens from the Oyama Formation as shown in Figure 6 (A-B). These variation may be due mainly to deformation during the fossilization process.

Leporimetis spectabilis lives in sandy bottoms of the tidal zone to more or less than 20

m depth south of Taiwan (Habe, 1977).

The specimens reported under the name of *Apolymetis* sp. from the Yatsuo-Kadonosawa Faunal Province are considered to be the present species. Some of them are examined and measured as follows;

Loc. Kakehata, Yatsuo-machi, Toyama Pref. (Kurosedani Formation)							
No.	Valve	Length	Height	Depth	H/L	D/L	Remarks
01	right	30.75	19.90	11.2/2	0.65	0.18	deformed
02	right	38.80	33.90	10.7/2	0.87	0.14	deformed
Loc. Sunakozaka, Ishikawa Pref. (Sunakozaka Formation)							
S1	left	33.35	27.00	5.6ca.	0.81	0.17	
Loc. Tohno, Ohmiya-machi, Ibaraki Pref. (Tamagawa Formation*)							
Loc. no.	Valve	Length	Height	Depth	H/L	D/L	Remarks
B-1	left	31.20	27.50	8.2	0.88	0.26	no deform
B-1	right	16.70	12.00	—	0.72	—	
E-2	left	19.60	15.60	—	0.80	—	
E-2	right	25.20	19.20	10.4/2	0.76	0.21	not deform
E-2	right	30.10	25.00	11.4/2	0.83	0.19	beak miss.
E-2	right	15.00	11.80	—	0.79	—	
D-1	left	40.90	29.90	7.6	0.73	0.19	deformed
D-2	left	28.2	21.0	—	0.74	—	
D-3	right	13.20	9.6	—	0.73	—	
C-1	right	37.0	25.40	—	0.69	—	depressed
E-4	right	34.55	26.70	7.0	0.77	0.20	no deform
E-4	right	32.20	22.90	13+/2	0.71	0.2+	conjoined

* unpublished collections used

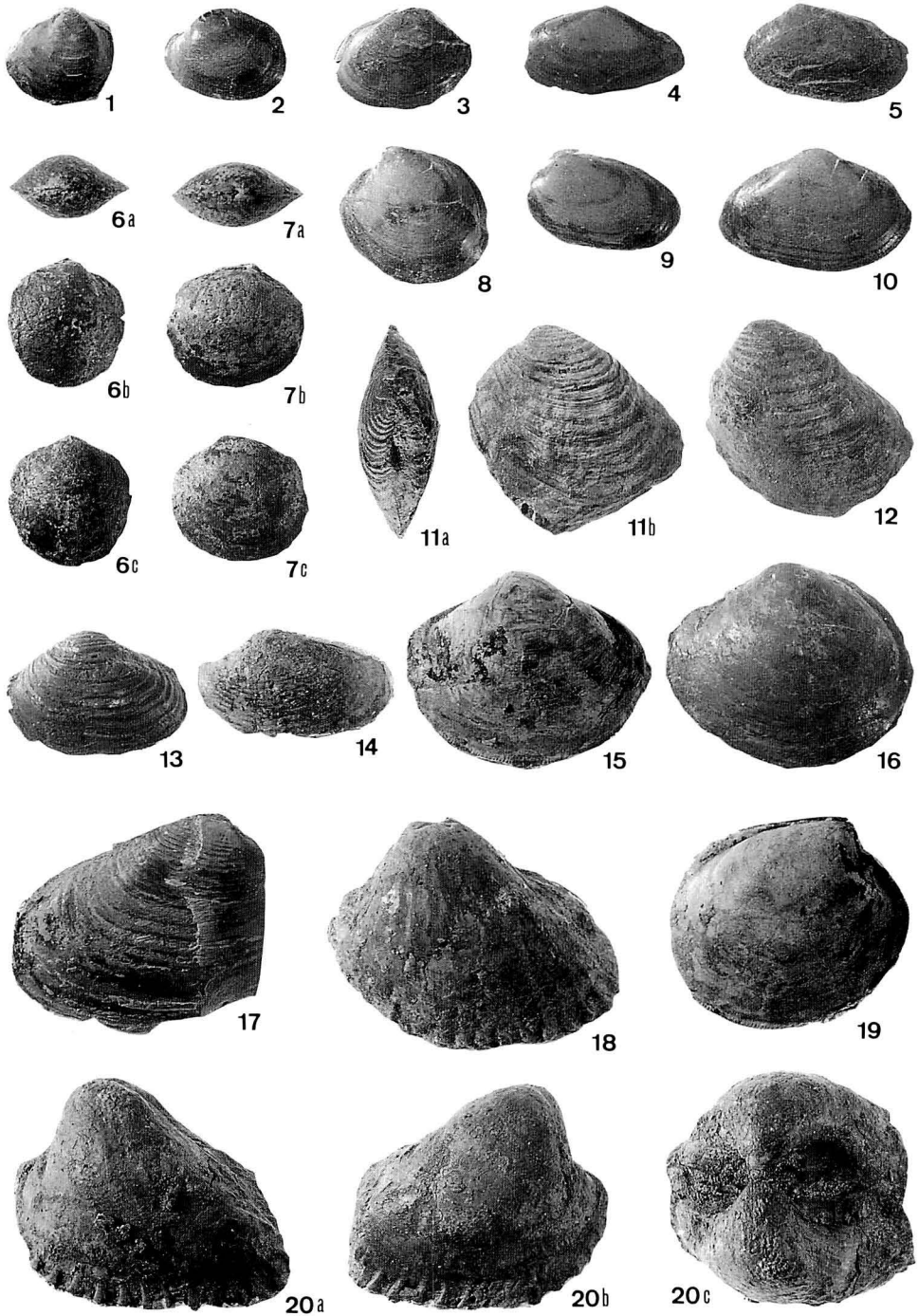


Figure 7. (All in natural size). **1, 2, 3.** *Cycladicama* cf. *takeyamai* (Otuka), Loc. 1(B). **4.** *Nitidotellina kagayamensis* (Ogasawara and Tanai), Loc. 1(B). **5, 9.** *Macoma* sp., Loc. 1(B). **6a-c, 7a-c, 8.** *Diplodonta ferruginata* Makiyama, Loc. 1(B). **10.** *Macoma* aff. *praetexta* (v. Martens), Loc. 1(B). **11a-b, 12, 13.** *Clementia papyracea* (Gray), Loc. 2. **14, 17.** *Paphia* cf. *ohiroi* Masuda, Loc. 2. **15, 16, 19.** *Cyclina japonica* Kamada, Loc. 1(A). **18, 20a-c.** *Anadara (Hataiarca) kakehataensis* Hatai and Nishiyama, Loc. 1(A).

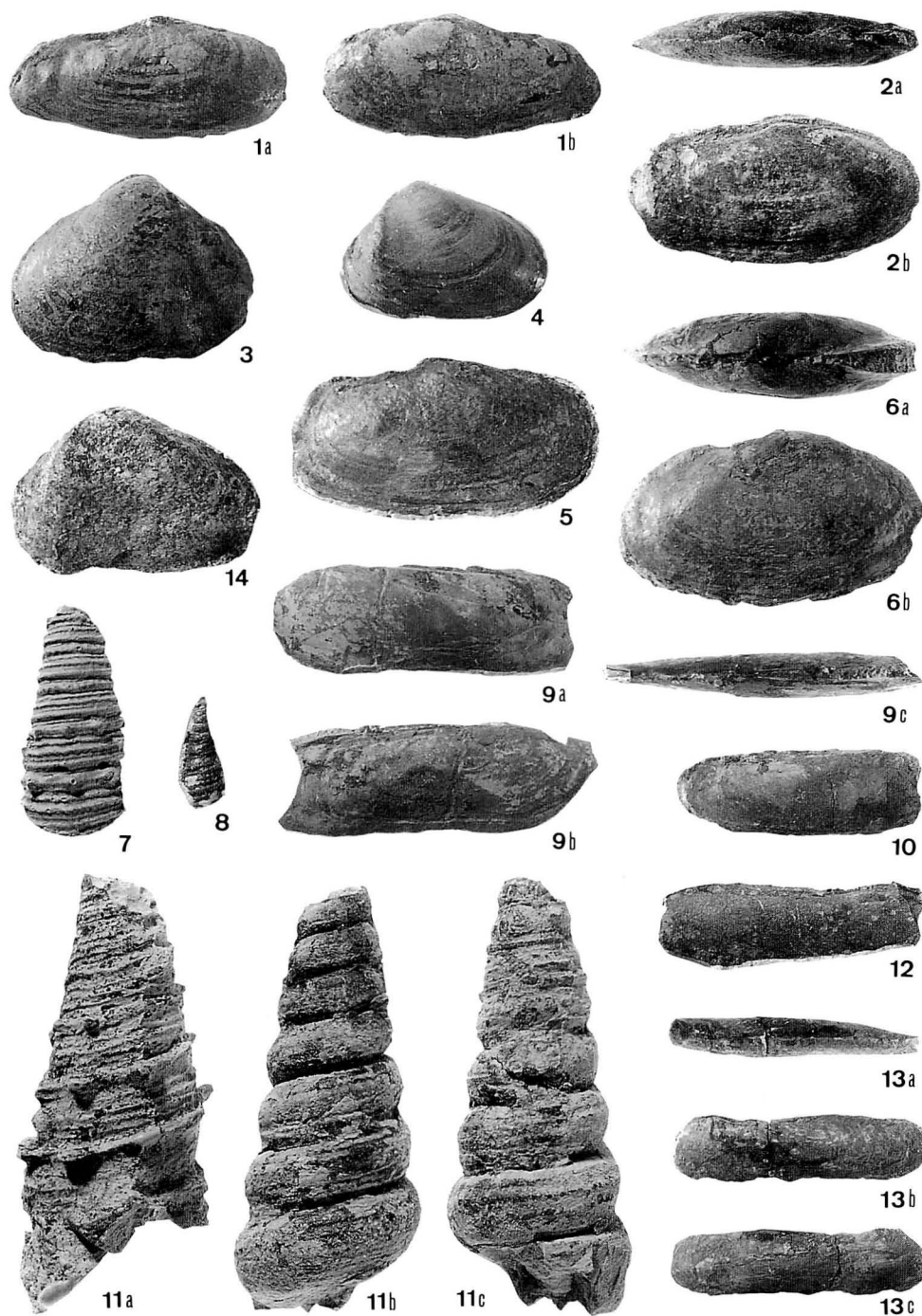
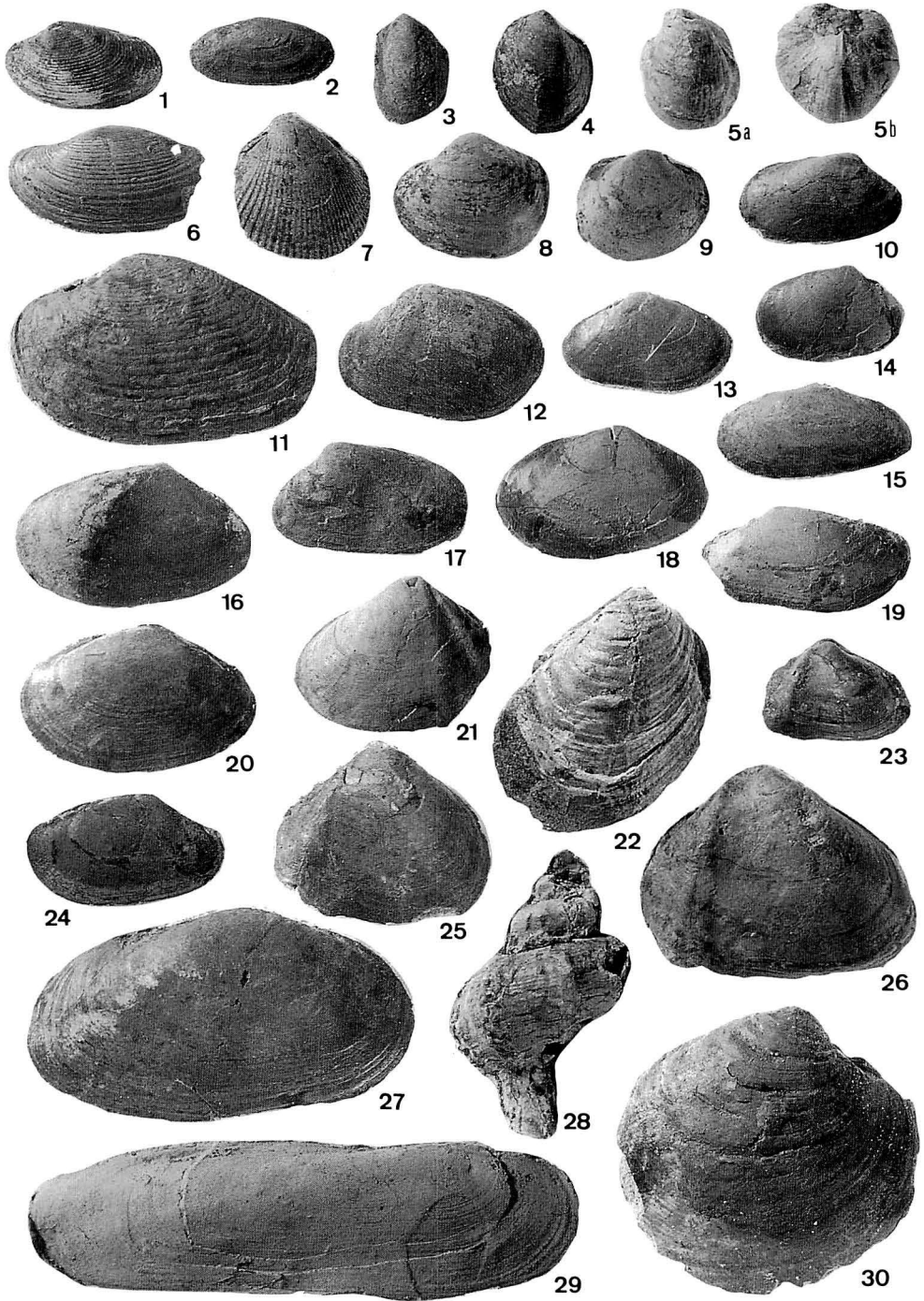


Figure 8. (All in natural size). **1a-b, 2a-b, 5, 6a-b.** *Hiatula minoensis* (Yokoyama), Loc. 1(A). **3, 4, 14.** *Leporimetis takaii* (Ogasawara and Tanai), 3, 14, Loc. 3, 4, Loc. 1(A). **7, 11a-c.** *Vicarya yokoyamai* Takeyama, Loc. 1(A). **8.** *Cerithideopsilla yatsuoensis* Tsuda, Loc. 1(B). **9a-c, 10, 13a-c.** *Cultellus izumoensis* Yokoyama, Loc. 2. **12.** *Cultellus* sp., Loc. 1(B).



Family Psammobiidae Fleming, 1828

Genus *Hiatula* Modeer, 1793*Hiatula minoensis* (Yokoyama)

Figures 8-1a-b, -2a-b, -5, -6a-b; 9-27.

Soletellina minoensis Yokoyama, 1926, p. 221, pl. 28, figs. 13, 15, 16; Masuda, 1955, pl. 19 fig. 9; Kanno, Amano and Noda, 1988, pl. 1, fig. 10.

Hiatula minoensis (Yokoyama), Ogasawara and Noda, 1978, p. 36-38, pl. 4, figs. 10-12, 15, 17-19, 21, 22; Taguchi, 1981, pl. 2, fig. 12; Ozawa, Nakagawa and Takeyama, 1986, pl. 14, fig. 4; Okamoto, Hayashi and Katsuhara, 1989, pl. 6, figs. 17-18.

Measurements (in mm)

Loc. Shimoshimizu						
Coll. no.	Valve	Length	Height	Depth	Remarks	
001	left	60.60	33.40	ca.5	beak situat. 33.3	
Loc. Sakashita						
00-1	left	47.20	24.60	—	ventral deformed	
-2	right	47.50	27.70	ca.14/2	not deformed	
-3	right	43.00	19.60	8.1/2	elongated type	
-4	right	45.35	23.70	9.4/2	not deformed	

Remarks.—This species is usually associated with *Vicarya*, *Anadara kakehataensis* and other characteristic species of the Arcid-Potamid Fauna as noted by Noda and Takahashi (1986).

Family Cultellidae Davies, 1935

Genus *Cultellus* Schumacher, 1817*Cultellus izumoensis* Yokoyama

Figures 8-9a-c, -10, -13a-c; 9-29.

Cultellus izumoensis Yokoyama, 1923, p. 5, pl. 2, figs. 1a-b; Yokoyama, 1925, p. 18, pl. 5, figs. 2, 3; Nomura, 1935, p. 220, pl. 16, figs. 16, 17; Otuka, 1941, p. 23, text-fig. 4; Kanno, 1956, p. 213, pl. 6, fig. 8; Iwai, 1961, pl. 1, fig. 19, Iwai, 1965, p. 45, pl. 12, fig. 15; Uozumi and Fujie, 1966, p. 153,

pl. 12, fig. 7; Hayashi and Miura, 1973, pl. 1, fig. 22; Shibata in Itoigawa *et al.*, 1974, p. 101, pl. 31, figs. 4, 5; Ogasawara, 1976, p. 57-58, pl. 14, figs. 16, 18; Ogasawara and Nomura, 1980, p. 89, pl. 11, figs. 5a-b, 9; Taguchi, 1981, pl. 2, figs. 13, 14; Itoigawa *et al.*, 1981-1982, p. 104, pl. 20, figs. 3a-b; Nakagawa, 1989, pl. 1, fig. 10

Measurements (in mm)

Loc. Shimoshimizu							
Coll. no.	Valve	Length	Height	Depth	H/L	D/L	Remarks
0001-1	left	86.90	25.20	4.6	0.29	0.053	
-2	left	85.0	23.80	7.0/2	0.28	0.041	conjoined
-3	left	79.70	28.00	ca.10/2	0.35	ca.0.063	conjoined
0002-1	left	51.0	17.40	7.3/2	0.34	0.072	conjoined
-2	left	37.5	13.20	7.1/2	0.35	0.095	conjoined
-3	left	38.70	10.60	2.6/2	0.27	0.085	elongated
Loc. Fujina Formation, Shimane Prefecture							
Holotype	left	44.0	15.0	—	0.34		conjoined

Remarks.—*Cultellus otukai* and *C. oyamensis* were both described as new species from the Oyama Formation by Ogasawara and Tanai (1952). Both are very similar to the present species. These two species may be synonyms, because they were described based on deformed specimens, although *C. oyamaensis* is more narrowly bladed than *C. otukai*. Moreover, their measurements and descriptions do not agree with the original illustrations. According to Kanno (1956), *C. otukai* is characterized by narrowly bladed shell, and parallel dorsal and ventral margins, and he showed a H/L ratio of about 0.26 and 1/4.2-1/4.3 for A/L (length of the anterior side). However, it is quite difficult to separate these two specimens into different species without measurements of shell inflation.

← **Figure 9.** (All in natural size). **1, 6, 11.** *Paphia* cf. *ohiroi* Matsuda, Loc. 2. **2, 15, 19.** *Tellina* cf. *notoensis* Masuda, Loc. 2. **3, 4.** *Solamen* cf. *forficatum* (Yokoyama), Loc. 2. **5a-b.** *Cardilia toyamaensis* Tsuda, Loc. 2. **7.** *Vasticardium ogurai* (Otuka), Loc. 2. **8, 9.** *Cycladicama* cf. *takeyamai* (Otuka), Loc. 1 (B). **10, 17.** *Tellina* cf. *osafuei* Taguchi, Loc. 1(B). **12, 14, 16, 18, 20.** *Macoma* aff. *praetexta* (v. Martens), Loc. 2. **13, 24.** *Psammacoma* aff. *awajiensis* (Sowerby), Loc. 2. **21, 23, 25, 26.** *Leporimetin takaii* (Ogasawara and Tanai), Loc. 1(A). **22, 30.** *Clementia papyracea* (Gray), Loc. 2. **27.** *Hiatula minoensis* (Yokoyama), Loc. 2. **28.** *Chicoreus* cf. *tiganourana* (Nomura), Loc. 1(B). **29.** *Cultellus izumoensis* Yokoyama, Loc. 2.

Class Gastropoda
 Family Potamididae
 Genus *Vicarya* d'Archiac
 and Haime, 1854
Vicarya yokoyamai Takeyama

Figures 8-7,—11a-c.

Vicarya verneuili yokoyamai Takeyama, 1933, p. 134-137, pl. 13, fig. 4.

Vicarya yokoyamai Takeyama. Kamada, 1960, pl. 30, figs. 3a-b, pl. 31, figs. 6, 7, 10; Itoigawa *et al.*, 1981-1982, p. 168-170, pl. 29, figs. 11a-13b; Takahashi, 1984, pl. 1, figs. 21-23; Sasaki and Ogasawara, 1986, pl. 6, figs. 10a-b; Itoigawa and Shibata, 1986, pl. 16, fig. 8; Kanno, Amano and Noda, 1988, p. 384-385, pl. 3, fig. 1; Nakagawa, 1989, pl. 3, figs. 1-4; Iwamura Res. Group, 1989, pl. 21, figs. 11-13.

Vicarya (Vicarya) yokoyamai Takeyama. Kamada, 1962, p. 151, pl. 18, figs. 13, 14.

Vicarya japonica Yabe and Hatai. Ozawa, Nakagawa and Takeyama, 1986, pl. 12, fig. 8.

Remarks.—Two ill-preserved specimens are examined. One of the specimens preserves 7 whorls and measures 29 mm in diameter and 67 mm + in height. Surface ornamentation is characterized by three primarily spiral cords and nine horizontally spired nodes in each whorl except for younger whorls. These surface spirals compare well with the type specimen described by Takeyama (1933) and also the specimens from the Kurosedani Formation, Toyama Prefecture. Another specimen (5 whorls preserved, Max. diameter ca. 17 mm and Height 34 mm+) has also three spirals and roundly elevated nodes just above the suture line.

Vicarya specimens are recorded from the Ohami Formation in Yamagata Prefecture in association with *Siratoria siratoriensis* and other characteristic species of the Kadonosawa Fauna (Sato *et al.*, 1986).

Genus *Cerithideopsilla* Thiele, 1929
Cerithideopsilla yatsuoensis (Tsuda)

Figure 8-8

Cerithidea (Cerithideopsilla) yatsuoensis Tsuda, 1959, p. 84, pl. 4, figs. 2-4; Sasaki and Ogasawara,

1986, pl. 6, figs. 4a-b; Nakagawa, 1989, pl. 2, figs. 4a-b.

Remarks.—Two fragmental specimens are examined. Surface is sculptured with three spiral cords and very weak spiral lines just above the suture. The main spirals have about 20 beadlike nodes. These spiral features are well comparable with the type specimen described from the Kurosedani Formation.

Cerithideopsilla minoensis Itoigawa is very similar to this species but can be separated from the present species in having about 13-16 longitudinal plicae.

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References

- Chiji, M. and IGCP-246 National Working Group of Japan, 1988: Paleogeographic change and bioevents related to the opening of the Sea of Japan. *Jour. Paleont. Soc. Korea*, vol. 4, no. 1, p. 55-60.
- Chinzei, K., 1978: Neogene molluscan faunas in the Japanese Islands: An ecologic and zoogeographic synthesis. *The Veliger*, vol. 21, no. 2, p. 155-170.
- , 1981: Marine biogeography of Japan during Miocene: A reconstruction based on benthonic molluscan faunas. *Fossils*, no. 30, p. 7-15. (*in Japanese*).
- , 1982a: Paleocology of oysters (1). *Ibid.*, no. 31, p. 27-34. (*in Japanese with English abstract*)
- , 1982b: Paleocology of oysters (2). *Ibid.*, no.

- 32, p. 19-27. (in Japanese)
- , 1986: Faunal succession and geographic distribution of Neogene molluscan faunas in Japan. *Palaeont. Soc. Japan, Spec. Papers*, no. 29, p. 17-32.
- and Iwasaki, Y., 1967: Paleoecology of shallow sea molluscan fauna in the Neogene deposits of Northeast Honshu, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 67, p. 93-113.
- Coan, E.V., 1971: The northwest American Tellinidae. *The Veliger*, vol. 14 (supplement), p. 1-63.
- Habe, T., 1977: *Systematics of Mollusca in Japan. Bivalvia and Scaphopoda*. 372 p. Zukan-no Hokuryukan, Tokyo.
- Hatai, K., 1956: A new *Globularia* (?) from Yamagata Prefecture. *Saito Ho-on Kai Mus., Res. Bull.*, no. 25, p. 1-2.
- and Nisiyama, S., 1940: A review of the paleontology of Yamagata Prefecture (Uzen Province), Northeast Honsyu, Japan. *Ibid.*, no. 19, p. 139-148.
- and —, 1949: A new Tertiary Mollusca from Japan. *Jour. Paleont.*, vol. 23, no. 1, p. 87-94, pls. 23-24.
- Hayashi, T. and Miura, Y., 1973: The Cenozoic sediments in the southern part of Okazaki City, Central Japan. *Bull. Aichi Univ. Educ., Nat. Sci.*, vol. 22, p. 133-149, pls. 1-2. (in Japanese with English abstract)
- Hayashida, A. and Torii, M., 1988: Opening process of southwestern part of the Sea of Japan— An attempt of paleogeographic reconstruction. *Gekkan Kaiyo-Kagaku (Monthly Marine Sci.)*, vol. 20, no. 11, p. 685-689. (in Japanese; title translated)
- Itoigawa, J. and Shibata, H., 1986: Molluscan fauna of the Setouchi Miocene Series, southwest Japan. *Palaeont. Soc. Japan, Spec. Papers.*, no. 29, p. 149-159, pls. 16-17.
- , — and Nishimoto, H., 1974: Molluscan fossils of the Mizunami Group. *Bull. Mizunami Fossil Mus.*, no. 1, p. 43-203, pls. 1-63. (in Japanese)
- , —, — and Okumura, K., 1981-1982: Miocene fossils of the Mizunami Group, Central Japan. 2. Molluscs. *Monogr. Mizunami Fossil Mus.*, no. 3-A, p. 1-53, pls. 1-52; *Ibid.*, 3-B, p. 1-330. (in Japanese with English descriptions)
- and Tsuda, K., 1986: Paleoecological significance of tropical molluscan assemblages in Japanese Miocene, with special reference to mangrove swamp assemblage. *Monogr. Mizunami Fossil Mus.*, no. 6, p. 171-182. (in Japanese with English abstract)
- Iwamura Research Group, 1989: New localities of *Vicarya* in the Iwamura Basin, Gifu Prefecture, Japan. *Bull. Mizunami Fossil Mus.*, no. 16, p. 117-120, pl. 21.
- Iwai, T., 1961: The Miocene molluscan fossils from the area southwest of Hirosaki City, Aomori Prefecture. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 41, p. 1-8, pl. 1.
- , 1965: The geological and paleontological studies in the marginal area of the Tsugaru basin, Aomori Prefecture, Japan. *Bull. Educ. Fac., Hirosaki Univ.*, no. 15, p. 1-68, pls. 12-20.
- Kamada, Y., 1960: On the associated occurrence of *Vicarya* and *Vicaryella* in the Japanese Tertiary, with the first description of a Paleogene species of *Vicarya* from Japan. *Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.), Spec. Vol.*, no. 4 (*Prof. S. Hanzawa Mem. Vol.*), p. 281-295, pls. 30-31.
- , 1962: Tertiary marine Mollusca from the Joban Coal-Field, Japan. *Palaeont. Soc. Japan, Spec. Papers.*, no. 8, p. 1-187, pls. 1-21.
- Kanno, S., 1956: Fossil and recent species of the cultellid molluscs from Japan. *Sci. Rep., Tokyo Kyoiku Daigaku, Sec. C (Geol., Mineral., Geogr.)*, no. 34, p. 209-218, pls. 5-6.
- , Amano, K. and Noda, H., 1988: *Vicarya* and its associated molluscan fauna from the Kunnui Formation in Oshamanbe, southwest Hokkaido. *Saito Ho-on Kai Spec. Pub. (Prof. T. Kotaka Commem. Vol.)*, p. 373-389, pls. 1-3.
- and Ogawa, H., 1964: Molluscan fauna from the Momijiyama and Takinoue districts, Hokkaido, Japan. *Sci. Rep., Tokyo Kyoiku Daigaku, Sec. C (Geol., Mineral., Geogr.)*, no. 81, p. 269-294, pls. 1-4.
- Kobayashi, T. and Horikoshi, M., 1958: Indigenous *Aturia* and some tropical gastropods from the Miocene of Wakasa in West Japan. *Japan. Jour. Geol. Geogr.*, vol. 29, nos. 1-3, p. 45-54, pls.
- Majima, R., 1989: Fossil and recent species of the Naticidae (Mollusca: Gastropod) in Japan. *Bull. Amer. Paleont.*, vol. 96, no. 331, p. 1-159, 14 pls.
- , and Takahashi, H., 1987: Miocene molluscus from the Kozono Formation, Saitama Prefecture, Central Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 148, p. 246-255.
- Makiyama, J., 1926: Tertiary fossils from north Kankyo-do, Korea. *Mem. Coll. Sci., Kyoto Imp. Univ., Ser. B.*, vol. 2, no. 3, p. 143-160, pls. 12-13.
- Masuda, K., 1955: Miocene Mollusca from Noto Peninsula, Japan. Part 1 (1). *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 20, p. 119-127, pl. 19.
- , 1966: Molluscan fauna of the Higashi-Innai Formation of Noto Peninsula, Japan. II. Remarks on molluscan assemblage and description of species. *Ibid.*, no. 64, p. 317-337, pls. 35-36.

- and Noda, H., 1976: *Checklist and bibliography of the Tertiary and Quaternary Mollusca of Japan, 1950-1974*. 494p. Saito Ho-on Kai, Sendai.
- Nakagawa, T., 1989: Intertidal molluscan assemblage in the Miocene Kunimi Formation, Fukui Prefecture, Central Japan. *Bull. Fukui Pref. Mus.*, no. 3, p. 23-45, 3 pls. (in Japanese with English abstract)
- and Takeyama, K., 1985: Fossil molluscan associations and paleo-environment of the Uchiura Group, Fukui Prefecture, Central Japan. *Bull. Mizunami Fossil Mus.*, no. 12, p. 27-47, pls. 15-24. (in Japanese with English abstract)
- Nishida, S. and Chihara, K., 1966: Neogene Tertiary stratigraphy in the Nishitagawa Coal-field, Yamagata-Niigata Prefecture, north Japan. *Contr., Dep. Geol. Mineral., Niigata Univ.*, no. 1, p. 31-57. (in Japanese with English abstract)
- Noda, H., 1966: The Cenozoic Arcidae of Japan. *Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.)*, vol. 38, no. 1, p. 1-161, pls. 1-14.
- , 1973: Geological significance of *Anadara (Hataiarca) kakehataensis* Hatai and Nisiyama in the Arcid-Potamid Fauna in Japan. *Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.), Spec. Vol. (Hatai Mem. Vol.)*, no. 6, p. 205-215, pl. 18.
- , Kikuchi, Y. and Nikaido, A., 1989: Arcid-Potamid Fauna from the Tama-gawa River area in Ibaraki Prefecture. *Geol. Soc. Japan, Abstracts with Programs, 96th Ann. Meet.*, p. 354. (in Japanese)
- and Takahashi, H., 1986: Distribution of *Anadara (Hataiarca) kakehataensis* and characteristics of the associated molluscan fauna in the early Middle Miocene of Japan. *Monogr., Mizunami Fossil Mus.*, no. 6, p. 49-58, pl. 5. (in Japanese with English abstract)
- Nomura, H., 1935: Miocene Mollusca from Siogama, Northeast Honshu, Japan. *Saito Ho-on Kai Mus., Res. Bull.*, no. 6, p. 193-232, pls. 16-17.
- Oda, M., 1986: Some aspects and problems concerned with microfossil biochronology for the Neogene in Central and Northeast Honshu, Japan. *Essays in Geol. (Prof. N. Kitamura Commem. Vol.)*, p. 297-312. (in Japanese with English abstract)
- Ogasawara, K., 1976: Miocene Mollusca from Ishikawa-Toyama area, Japan. *Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.)*, vol. 46, no. 2, p. 33-78, pls. 11-15.
- , 1988: Neogene bio-events in terms of warm- and cold-water molluscs in Northeast Honshu, Japan. *Osaka City Nat. Hist. Mus.*, p. 49-70. (in Japanese with English abstract)
- and Morita, R., 1990: A new Miocene gastropod species cooccurred with *Paleoparadoxia* specimens from the Yanagawa Formation, Fukushima Prefecture, Northeast Honshu, Japan. *Saito Ho-on Kai Mus. Nat. Hist., Res. Bull.*, no. 58, p. 25-30, pl. 1.
- and Noda, H., 1978: Arcid-Potamid fauna (Mollusca) from the Tsukinoki Formation, Sennan district, Miyagi Prefecture, Northeast Japan. *Saito Ho-on Kai Mus., Res. Bull.*, no. 46, p. 21-44, pls. 3-4.
- and Nomura, R., 1980: Molluscan fossils from the Fujina Formation, Shimane Prefecture, San-in district, Japan. *Prof. S. Kanno Mem. Vol.*, p. 79-98, pls. 9-12.
- Ogasawara, Kenzo and Tanai, T., 1952: The discovery of new Miocene fauna in the northern part of Nishitagawa Coal-field, Yamagata Prefecture, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 7, p. 205-212, pl. 19.
- Okamoto, K., Hayashi, Y. and Katsuhara, M., 1989: Fossil Mollusca from the Miocene at Myoga, Shobara City, a new locality of *Geloina* in Shobara, and the relationship between *Tateiwaia* species and substrata—study of the Bihoku Group II—. *Bull. Mizunami Fossil Mus.*, no. 16, p. 43-53, pls. 5-7. (in Japanese with English abstract)
- Otuka, Y., 1934: Tertiary structures of the northwestern end of the Kitakami Mountainland, Iwate Prefecture, Japan. *Bull. Earthq. Res. Inst.*, vol. 12, pt. 3, p. 566-638, pls. 44-51.
- , 1938: Mollusca from the Miocene of Tyugoku, Japan. *Jour. Fac. Sci., Imp. Univ. Tokyo*, sec. 2, vol. 5, pt. 2, p. 21-45, pls. 1-4.
- , 1941: Fossil Mollusca from Tazima, Hyogo Prefecture, Japan. *Japan. Jour. Geol. Geogr.*, vol. 18, nos. 1-2, p. 21-24.
- Oyama, K., 1950: Studies of fossil molluscan biocoenosis, No. 1. Biocoenological studies on the mangrove swamps, with descriptions of new species from Yatsuo Group. *Rep. Geol. Surv. Japan*, no. 132, p. 1-16, pls. 1-3.
- Ozawa, T., Nakagawa, T. and Takeyama, K., 1986: Middle Miocene molluscan fauna of the Uchiura Group, Wakasa Province, southwest Japan. *Palaeont. Soc. Japan, Spec. Papers.*, no. 29, p. 135-148, pls. 12-15.
- Ozawa, A., Ohguchi, T. and Takayasu, T., 1979: *Geology of the Asamai district*. Quadrangle Ser., scale 1:50,000, Geol. Surv. Japan, 53 pp. pls. 1-4. (in Japanese with English abstract)
- Saito, T. et al., 1986: Neogene paleo-magneto- and microbiochronological scale of Northeast and Central Japan. In, Kitamura, N. ed., *Cenozoic Arc Terrane of Northeast Honshu, Japan*. 1 suppl. fig. Hobundo, Sendai. (in Japanese; title translated)

- Sasaki, O. and Ogasawara, K., 1986: Intertidal molluscan assemblage from the Miocene Sunakozaka Formation, Ishikawa-Toyama area, Hokuriku district, Japan. *Mem. Natn. Sci. Mus, Tokyo*, no. 19, p. 79-89, pls. 5-6. (in Japanese with English abstract)
- Sasaki, T., 1991: Molluscan assemblages of the Sugota Formation from Dewa Hill of Akita Prefecture. *Palaeont. Soc. Japan, Abstracts with Programs, 1991 Ann. Meet., Sendai*, p. 34. (in Japanese; title translated)
- Sato, H., Yamaji, A. and Ishii, T., 1986: Traverse Route No. 22 of Tohoku Honshu Arc (Atsumi-Tsuruoka-Obanasawa-Matsushima). 26 pp, 1 geologic map, 1 Geologic section map. In, Kitamura, N. ed., *Cenozoic Arc Terrane of Northeast Honshu, Japan*. Hobundo, Sendai. (in Japanese; title translated)
- Sato, Y., Yanagisawa, Y. and Yamamoto, T., 1989: Arcid-Potamid fauna of the Myozawabashi Formation, Yamagata Prefecture, northeast Japan. *Palaeont. Soc., Japan, Abstracts with Programs, 1989 Ann. Meet., Kyoto*, p. 83. (in Japanese)
- Shimakura, M. and Hatai, K., 1940: Notes on the geology of the western part of Nisi-Tagawa district, Yamagata Prefecture (Uzen Province), Northeast Honshu. *Saito Ho-on Kai Mus., Res. Bull.*, no. 19, p. 149-152, pl. 6.
- Shuto, T., 1960: On some pectinids and Venerids from the Miyazaki Group (Palaeontological study of the Miyazaki Group-VII). *Mem. Fac. Sci., Kyushu Univ. Ser. D (Geol.)*, vol. 9, no. 3, p. 119-149, pls. 12-14.
- Taguchi, E., 1981: *Geloina/Telescopium* bearing molluscan assemblages from the Katsuta Group, Okayama Prefecture-with special reference to brackish faunal zonation in the Miocene of Japan. *Bull. Mizunami Fossil Mus.*, no. 8, p. 7-20, pls. 2-4.
- Takahashi, H., 1984: Molluscan assemblages from the Miocene Nakayama Formation in the Kadono district, Joban Coal-Field, Fukushima Prefecture. *Fossils*, no. 36, p. 1-17. (in Japanese with English abstract)
- Takeyama, T., 1933: Notes on the genus *Vicarya*, with description of two Japanese forms. *Japan. Jour. Geol. Geogr.*, vol. 10, nos. 3-4, p. 129-144, pl. 13.
- Tanai, T., 1951: Geologic structure of northern area of Nishitagawa Coal-field, Yamagata Prefecture. *Jour. Geol. Soc. Japan*, vol. 57, no. 668, p. 157-171. (in Japanese with Latin abstract)
- Tsuchiya, N., Ozawa, A. and Ikebe, Y., 1984: Geology of the Tsuruoka district. Quadrangle Series, scale 1:50,000. Geol. Surv. Japan, 77 pp. (in Japanese with English abstract)
- Tsuda, K., 1959: New Miocene molluscs from the Kurosedani Formation in Toyama Prefecture, Japan. *Jour. Fac. Sci., Niigata Univ., Ser. 2*, vol. 3, no. 2, p. 67-110, pls. 1-7.
- , 1960: Paleo-ecology of the Kurosedani Fauna. *Jour. Fac. Sci., Niigata Univ.*, vol. 3, no. 4, p. 171-203.
- , 1965: Neogene molluscan assemblages in the Inner zone of Northeast Japan-with special reference to the Middle Miocene assemblages. *Fossils*, no. 10, p. 20-23. (in Japanese)
- , Itoigawa, J. and Yamanoi, T., 1986: Mangrove swamp fauna and flora in the Middle Miocene of Japan. *Palaeont. Soc. Japan, Spec. Papers.*, no. 29, p. 129-134.
- Uchimura, R. 1991: Mixed zone of warm- and cold-water species at early Middle Miocene-An example of the Miocene Furanui Formation of Hokkaido. *Palaeont. Soc. Japan, Abstracts with Programs, 140th Regular Meet., Chiba*, p. 48. (in Japanese; title translated)
- Uozumi, S. and Fujie, T., 1966: Neogene molluscan fauna in Hokkaido. Part 2. Description of the Okushiri fauna associated with *Vicarya*, from Okushiri Island, Southwest Hokkaido. *Jour. Fac. Sci., Hokkaido Univ., Ser. 4 (Geol. Mineral.)*, vol. 13, no. 2, p. 139-163, pls. 11-13.
- Yokoyama, M., 1923: On some fossil Mollusca from the Neogene of Izumo. *Japan. Jour. Geol. Geogr.*, vol. 2, no. 1, p. 1-9, pls. 1-2.
- , 1925: Molluscan remains from the uppermost part of the Joban Coal-Field. *Jour. Coll. Sci., Imp. Univ. Tokyo*, vol. 45, art. 5, p. 1-34, pls. 1-6.
- , 1926: Molluscan fossils from the Tertiary of Mino. *Jour. Fac. Sci., Imp. Univ. Tokyo, Sec. 2*, vol. 1, pt. 7, p. 213-227, pl. 28.

Ajiri 網尻, Bihoku 備北, Chiganoura 千賀ノ浦, Doh 土, Irakawa 五十川, Kadono 遠野, Kakehata 掛畑, Katsuta 勝田, Kozono 子園, Kunnui 訓縫, Kunugidaira 櫛平, Kurosedani 黒瀬谷, Kusanagi 草薙, Nakayama 中山, Ohami 大網, Okura 大蔵, Okushiri 奥尻, Oyama 大山, Sakashita 坂下, Shimoike 下池, Shiogama 塩釜, Shimoshimizu 下清水, Shorenji 生蓮寺, Sugota 須郷田, Sunakozaka 砂子坂, Tamagawa 玉川, Tsurikake 釣懸, Tsuruoka 鶴岡, Yanagawa 梁川, Yoshino 吉野, Zempoji 善宝寺.

本邦中期中新世における熱帯性貝類化石の縁辺相；東北本州鶴岡市の大山層貝類化石の例：山形県鶴岡市に分布する初期中中新世大山層の貝類化石は *Geloina*, *Vicarya*, *Leporimetis* 属などを含み、これらの属の古生物地理分布に基づけば当時の熱帯海域マングローブ沼に相当する事が考えられる。この大山層の貝類化石は Arcid-Potamid Fauna とともに深部内生腐泥食者である多くの Tellinids (*Macoma*, *Psammacoma*, *Nitidotellina*, *Leporimetis*) 属が産する事で特徴づけられる。このような組成的特徴はこの地域が潮間帯から内湾域に未固結の砂質泥底が広がっていた事を指示する。古生物地理的観点からみると、大山層と秋田県南部の間、及び常磐炭田地域の上遠野地域の中山層とその北部の間に明瞭な貝類化石組成上の差異が認められる。この差異は初期中中新世における熱帯と亜熱帯の浅海性海洋生物区の境界がこれらの間にあったために生じたものと考えられる。即ち鶴岡市の大山層は当時の熱帯海中気候の最北部に相当していたと結論づけられる。本論ではこれらの議論に加えて大山層だけでなく本邦から産する *Leporimetis takaii* についての分類学的考察も行った。

小笠原憲四郎・長澤一雄

943. FOSSIL DECAPOD CRUSTACEANS FROM THE MANDA GROUP (MIDDLE EOCENE), KYUSHU, JAPAN

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Abstract. Five species, *Eucalliax yoshihiro* sp. nov., *Prohomola japonica* (Yokoyama, 1911) gen. nov., *Raninoides nodai* sp. nov., *Portunites kattachiensis* sp. nov. and *Branchioplax pentagonalis* (Yokoyama, 1911) comb. nov. are described from the Middle Eocene (Okinoshiman) Manda Group in Kattachi, Omuta City, Fukuoka Prefecture, Kyushu, Japan. The decapod fauna from the Manda Group is closely related to those from the western and central Tethyan realms.

Key words. Decapoda, Crustacea, new species, new genus, Manda Group, Middle Eocene, Kyushu.

Introduction

The Middle Eocene Manda Group (Nagao, 1926) is distributed in the Omuta district, Middle Kyushu. This group contains a rich marine fauna and there have been several palaeontological studies, such as molluscs by Yokoyama (1911), Nagao (1928), Mizuno (1963) and Tomida *et al.* (1992) *etc.*, and elasmobranchs by Yabumoto (1989). The first crabs to be described were *Homolopsis japonicus* Yokoyama, 1911 and *Xanthilites pentagonalis* Yokoyama, 1911 from the Miike Coalfield in Omuta City. Tomita *et al.* (1992) figured, but did not describe, three species of crabs as *Oncinopus* sp., *Carcinoplax* sp. and *Leucosia* sp., all from the Manda Group.

In this paper, I describe five species, three new, in five genera of decapods from the Manda Group, collected by S. Noda. In addition, Yokoyama's two species from the Manda Group are redescribed, a new genus, *Prohomola*, is proposed to accommodate

Homolopsis japonicus Yokoyama, 1911, and the palaeobiogeography of the species involved is discussed.

Specimens prefixed KMNH IVP are in the Kitakyushu Museum of Natural History (6, Nishihonmachi 3-chome, Yahatahigashiku, Kitakyushu, 805), ESN80005 is in the Department of Earth and Planetary Sciences, School of Science, Nagoya University (Chikusa, Nagoya, 464-01), and others are in the Noda collection (294, Miike, Omuta, 837).

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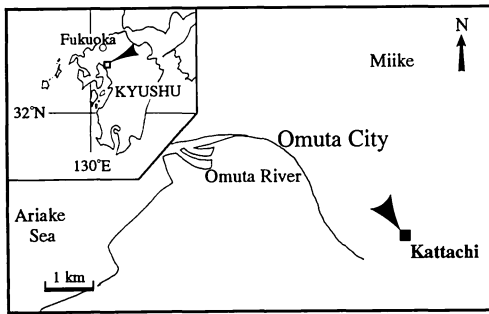


Figure 1. Locality map.

study.

Locality and geologic note

The Middle Eocene decapods were collected from the Kattachi Formation, Manda Group exposed at Kattachi ($130^{\circ}28'52''\text{E}$, $33^{\circ}00'45''\text{N}$), Omuta City (Figure 1). In this area, the Manda Group overlying the Omuta Group, is divided into the Kattachi and Yotsuyama Formations in ascending order (Nagao, 1926; Matsushita, 1949; Tomida *et al.*, 1992). According to Mizuno (1962, 1964), the Manda Group is correlated with the Okinoshiman stage, set chronologically by Ozaki *et al.* (1991) and Mizuno (1992) in the late Middle Eocene (Bartonian).

Decapods occur in nodules of the lowermost sandstone of the Kattachi Formation in association with many molluscs, *Crassatellites fuscus* Yokoyama, *Venericardia nipponica* Yokoyama, *V. mandarica* (Yokoyama), *Mazzalina miikensis* (Nagao), *Petrochus eocenicus* Kuroda and Urata, *Aturia nagoi* Kobayashi, *A. matsushitai* Kobayashi, and elasmobranchs, *Carcharodon nodai* Yabumoto, *Striatolamina macrotta* (Agassiz).

Systematic Palaeontology

- Infraorder Thalassinidea Latreille, 1831
- Superfamily Axioidea Huxley, 1879
- Family Callianassidae Dana, 1852
- Subfamily Eucalliinae Manning and Felder, 1991

Genus *Eucalliix* Manning and Felder, 1991

Type species.—By original designation *Callianassa quadracuta* Biffar, 1970.

Geologic range.—Eocene to Recent.

Eucalliix yoshihiro sp. nov.

Figures 2-1-6; 3-1-4

Etymology.—From Yuei Yoshihiro who collected the type specimen.

Diagnosis.—Chelipeds large, heterochelate; propodus of major cheliped sparsely granulate on mesial and lateral surfaces; palm slightly broader than long; minor cheliped slightly shorter than major cheliped; propodus also sparsely granulate on mesial and lateral surfaces; fingers elongate, longer than palm; carpus short; merus rhomboidal, with longitudinal carina on lateral surface.

Description.—The chelipeds are large and heterochelate. The propodus of the major cheliped is about 1.6 times longer than broad. The sharp dorsal and mesial margins are dentate. The gently convex mesial and lateral surfaces are sparsely granulate distally. The palm is slightly broader than long and about 1.3 times the length of the fixed finger. The propodus of the minor cheliped is slightly shorter and more slender than that of the major cheliped. The propodus which is twice as long as broad bears irregular dentications on the ventral and dorsal margins, and is sparsely ornamented with granules on the lateral and mesial surfaces, distally. The palm is about 1.2 times broader than long and shorter than the elongate fixed finger. The carpus is short. The merus, with a longitudinal carina on the lateral surface, is rhomboidal in lateral view and longer than broad.

The 6th abdominal somite is slightly wider than long. There are two transverse sutures extending one-fifth of the width on each side at the distal third, and they unite with longitudinal sutures. On the posterior margin, a central suture reaches the horizontal suture.

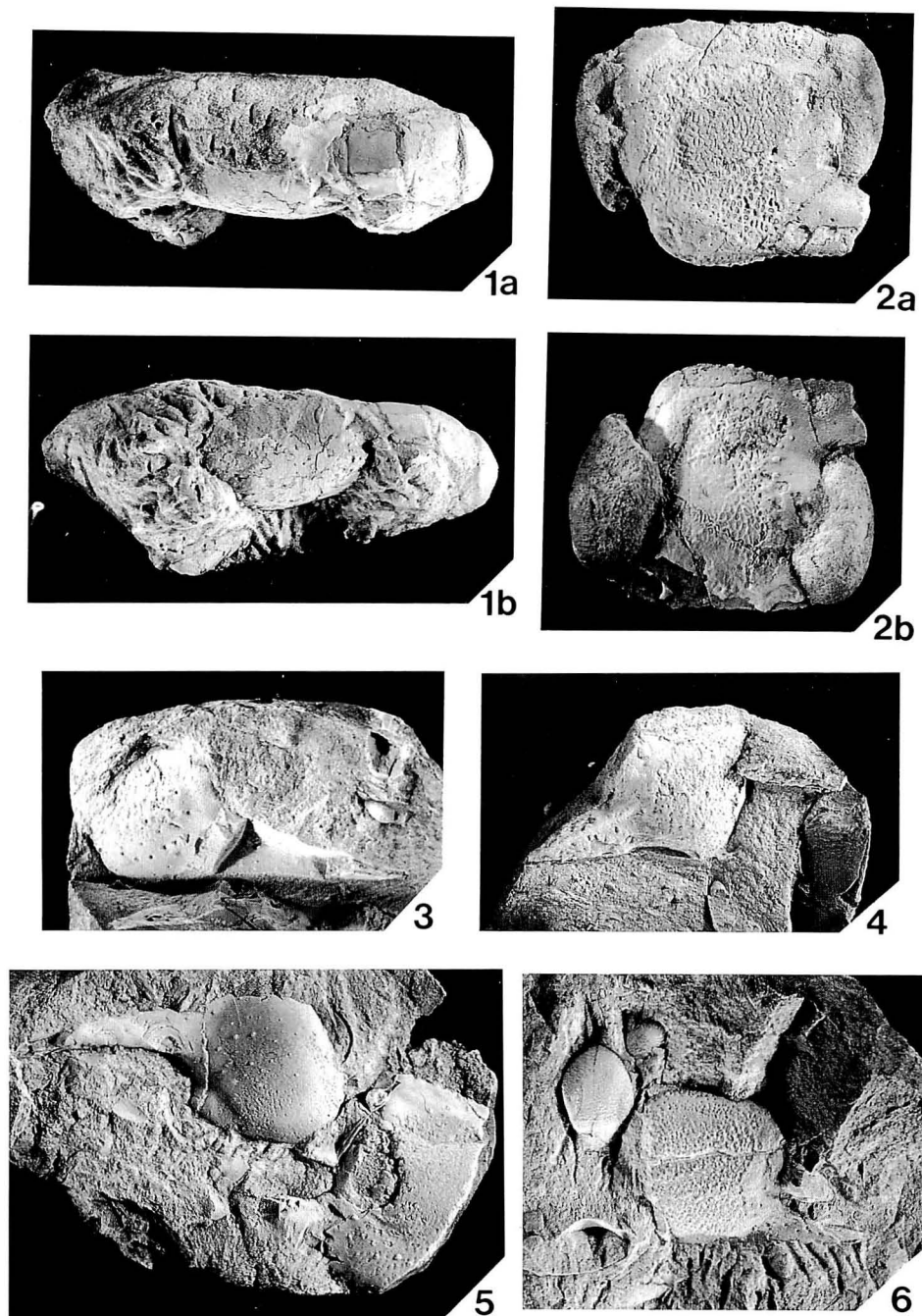


Figure 2. *Eucalliax yoshihiro* sp. nov. **1**, branchial region and abdominal segments, Noda collection (5954), a, dorsal; b, left view. **2**, propodus of right cheliped, paratype (KMNH IVP 300,002), a, lateral; b, mesial view. **3**, propodus of right cheliped, paratype (KMNH IVP 300,003), lateral view. **4**, propodus of left cheliped, paratype (KMNH IVP 300,004), lateral view. **5**, propodus of left and right chelipeds, holotype (KMNH IVP 300,001). **6**, right cheliped, paratype (KMNH IVP 300,005). All figures $\times 1.5$.

Discussion.—The present new species is readily distinguished from the Late Eocene *Callianassa muratai* Nagao, 1932 and *C. elongatodigitata* Nagao, 1941 from Hokkaido in that the palm of the major cheliped is shorter and the minor cheliped is larger.

This species is one of the dominant elements from the Kattachi Formation, Manda Group.

Repository.—KMNH IVP 300, 001 (Holotype); KMNH IVP 300, 002–300, 009 (Paratypes); Noda collection (5954).

Infraorder Brachyura Latreille, 1803

Section Podotremata Guinot, 1977

Subsection Archaeobrachyura Guinot, 1977

Superfamily Homoloidea de Haan, 1839

Family Homolidae de Haan, 1839

Genus *Prohomola* gen. nov.

Type species.—By monotypy *Homolopsis japonicus* Yokoyama, 1911; Middle Eocene, Japan; gender, feminine.

Etymology.—Indicating an early member of the *Homola* Group.

Diagnosis.—Carapace longitudinally ovate, tapering anteriorly; dorsal surface flattened, granulated, without spines; mesogastric lobe with a median tubercle; rostrum slender, simple, downturned; pseudorostral spine triangular, short, projecting dorsally.

Discussion.—In the outline of the carapace, the present new genus resembles *Paromola* Wood-Mason and Alcock, 1891 *emend.* Guinot and Forges (in press), but differs in having the dorsal surface without spines and a short pseudorostral spine which does not overreach the rostral spine. *Prohomola* gen. nov. is easily distinguished from the only other hitherto known Palaeogene homolid genus *Palehomola* Rathbun, 1926 because in *Palehomola* the rostrum consists of two horns. *Prohomola* has pseudorostral spines and the mesogastric lobe has a median tubercle, whereas the mesogastric lobe of *Homolopsis* Bell, 1863 and *Zygastrorcarinus* Bishop, 1983 has three nodes arranged in a triangle

and there are no pseudorostral spines.

Geologic range.—Late Middle Eocene (Okinoshiman).

Prohomola japonica (Yokoyama, 1911)
comb. nov.

Figures 3–5–7

Homolopsis japonicus Yokoyama, 1911, p. 12, pl. 3, fig. 4.

Paromola japonicus (Yokoyama). Jenkins, 1977, p. 4.
(*non Paromola japonica* Parisi, 1915)

Oncinopus sp. Tomita *et al.*, 1992, pl. 17, fig. 10.

Zygastrorcarinus japonica (Yokoyama). Bishop and Brannen, 1992, p. 321.

Diagnosis.—As for genus.

Description.—The carapace is longitudinally ovate in outline and tapers anteriorly. The forwardly directed rostrum is downturned, slender and simple. The robust pseudorostral spines are short, triangular, and project dorsally. The anterolateral margins with a sharp epibranchial spine, are gently convex. The irregularly tuberculated posterolateral margins are gently rounded. The flattened dorsal surface is ornamented with granules which vary in size. The regions are well defined. A deep groove separates the slightly swollen protogastric lobes, each with two nodes transversely arranged, from the anterior mesogastric process. There is a large median tubercle on the slightly convex mesogastric lobe. The inflated urogastric lobe is bilobed. The narrow cardiac lobe, with a shallow median depression, is longitudinally vaulted. The cervical and branchiocardiac grooves are well developed. Two nodes one above the other are present on the gently convex hepatic lobe. The gently elevated epibranchial lobes, divided by a shallow oblique groove, are bounded by the cervical, branchiocardiac and gastrocardiac grooves. The mesobranchial lobes are gently convex. The metabranchial lobes are separated from the cardiac region by deep postcardiac markings and the intestinal lobe is flattened. The *linea homolica* is present.

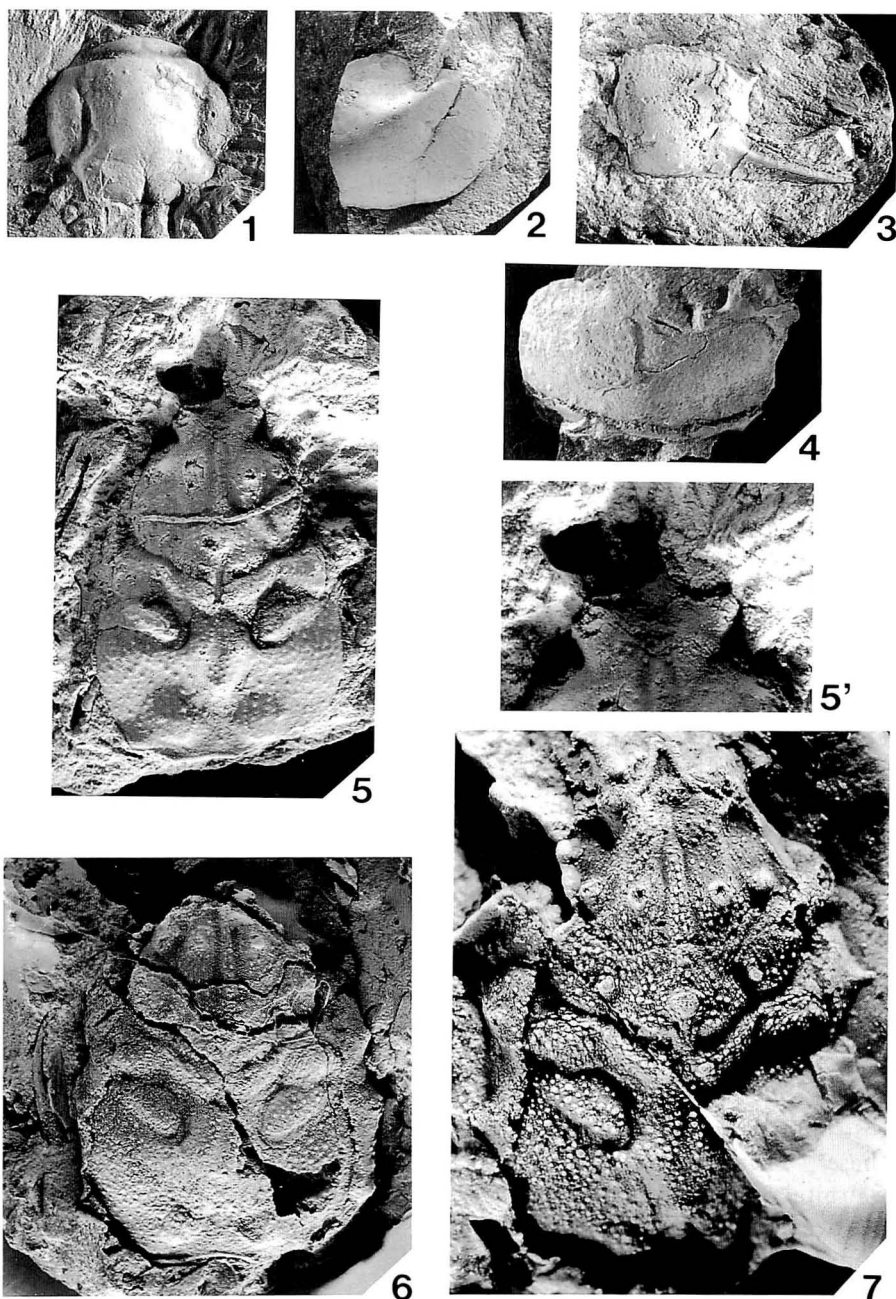


Figure 3. 1-4, *Eucalliax yoshihiroii* sp. nov. 1, sixth abdominal segment, paratype (KMNH IVP 300,006), $\times 2.3$, dorsal view. 2, merus of left cheliped, paratype (KMNH IVP 300, 007), $\times 2.0$, lateral view. 3, propodus of right cheliped paratype (KMNH IVP 300,008), $\times 1.5$, lateral view. 4, carpus of right cheliped, paratype (KMNH IVP 300,009), $\times 2.8$, lateral view. 5-7, *Prohomola japonica* (Yokoyama, 1911) gen. nov. 5, carapace, Noda collection (5988), $\times 2.8$, dorsal view. 5', rostrum of figure 5, $\times 6.2$. 6, carapace, KMNH IVP 300, 010, $\times 3.2$, dorsal view. 7, plaster cast of outer mould of KMNH IVP 300,010, $\times 4.8$, dorsal view.

Remarks.—Yokoyama's (1911) original description of this species was founded on a single specimen taken at a depth of 489 feet from a shaft at the Miike Coalfield.

Repository.—KMNH IVP 300, 010; Noda collection (5988).

Superfamily Raninoidea de Haan, 1839

Family Raninidae de Haan, 1839

Genus *Raninoides* H. Milne Edwards, 1837

Type species.—By monotypy *Ranina laevis* Latreille, 1825.

Geologic range.—Eocene to Recent.

Raninoides nodai sp. nov.

Figures 4-2-8

Etymology.—From Sakae Noda who collected the type specimen.

Diagnosis.—Carapace longitudinally ovoid; dorsal surface smooth, with a weak median ridge; orbitofrontal margin 0.75 of carapace width; anterolateral margin with long hepatic spine.

Description.—The carapace is longitudinally ovoid in outline and the length, excluding the hepatic spine, is 1.5-1.6 times the width. The finely granulated dorsal surface with a weak median ridge, is slightly convex longitudinally. The regions are not defined. The posterior gastric pits are present and attractor epimeralis muscle scars are weakly marked. The wide orbitofrontal margin occupies 0.75 of the carapace width. The triangular rostrum is flattened and as long as wide at the base. There are two deep fissures in the upper orbital margin and the U-shaped inner fissure is deeper than the V-shaped outer one. The outer orbital spine is bifid; the external branch, directed laterally, is broadly triangular in outline and longer than the sharply triangular internal branch. The inner orbital spine on either side of the rostrum is shorter than the outer orbital spine and directed obliquely outwards. The anterolateral margins are convex and there is a long hepatic spine projecting forwards and

outwards. Sigmoid posterolateral margins converge posteriorly. The pterygostomian regions are inflated and the long buccal area tapers anteriorly.

Left and right chelipeds are present, but badly preserved. The propodus has two forwardly directed acutely triangular spines on the ventral margin and one on the dorsal margin. The sharp fixed finger is as long as the palm, strongly deflexed ventrally and has 6 teeth on the occludent margin. The slender dactylus is as long as the fixed finger and strongly down-curved.

Discussion.—The present new species closely resembles *Raninoides vaderensis* Rathbun, 1926 from the Eocene of North America, but differs in having a weak median ridge on the dorsal surface and a long hepatic spine. *R. nodai* sp. nov. appears to have a post-frontal ridge, but it is much weaker than that of *R. vaderensis*.

Raninoides nodai sp. nov. occurs in high density conditions at Kattachi.

Repository.—KMNH IVP 300, 011 (Holotype); KMNH IVP 300, 012-300, 015 (Paratypes); Noda collection (N676).

Section Heterotremata Guinot, 1977

Superfamily Portunoidea Rafinesque, 1815

Family Portunidae Rafinesque, 1815

Subfamily Carcininae MacLeay, 1838

Genus *Portunites* Bell, 1858

Type species.—By monotypy *Portunites incerta* Bell, 1858.

Geologic range.—Eocene to Miocene?

Portunites kattachiensis sp. nov.

Figures 5-1, 3

Etymology.—From "Kattachi", a fossil-bearing locality name.

Diagnosis.—*Portunites* with nearly straight frontal margin with 4 blunt lobes, anterolateral margin bearing 5 teeth, the last produced laterally.

Description.—The carapace is hexagonal in

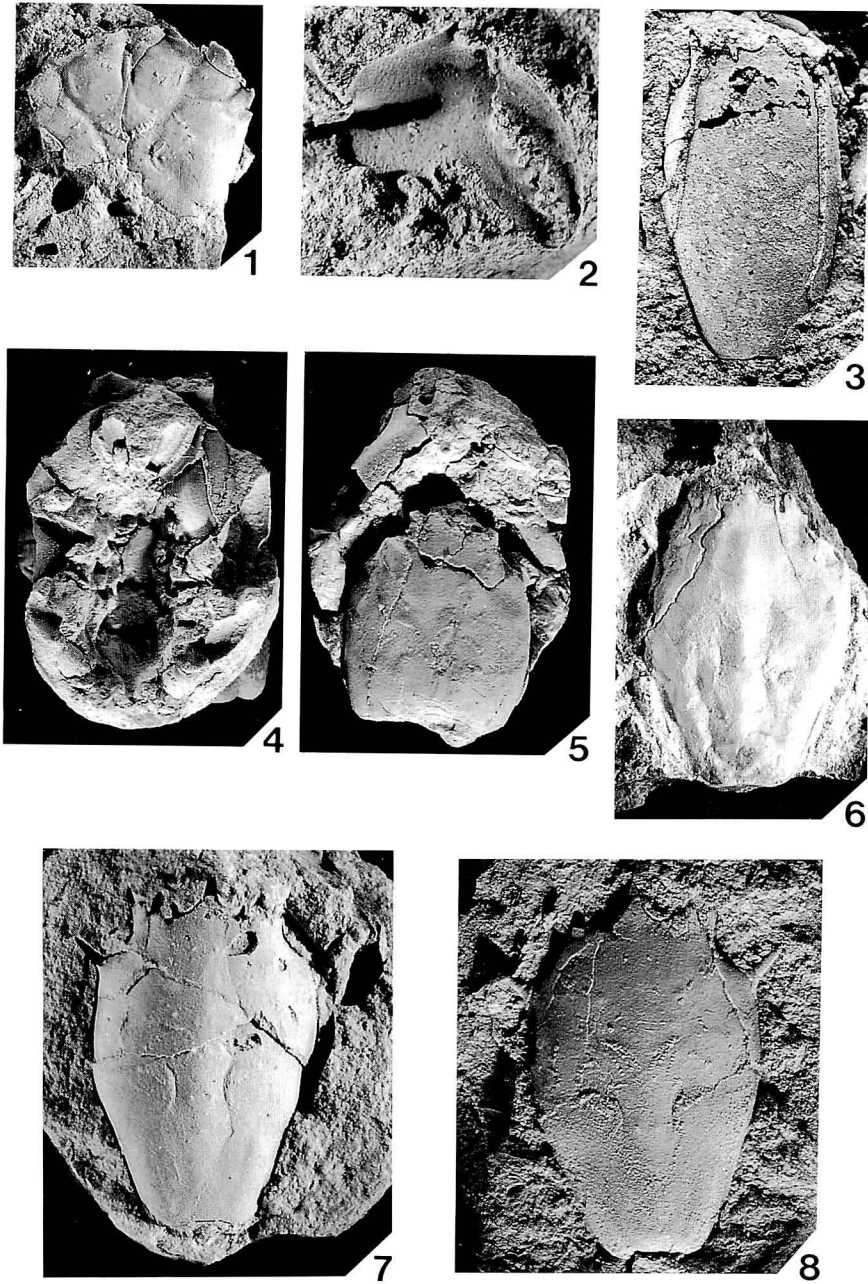


Figure 4. 1. *Branchioplax pentagonalis* (Yokoyama, 1911) comb. nov., carapace, KMNH IVP 300,017, $\times 1.5$, dorsal view. 2-8, *Raninoides nodai* sp. nov. 2, right cheliped, holotype, (KMNH IVP 300,011), $\times 3.8$, lateral view. 3, carapace, paratype (KMNH IVP 300,012), $\times 3.0$, dorsal view. 4, thoracic sterna and third maxillipeds, paratype (KMNH IVP 300,013), $\times 2.0$, ventral view. 5, carapace and left cheliped, paratype (KMNH IVP 300,014), $\times 1.5$, dorsal view. 6, carapace, paratype (KMNH IVP 300,015), $\times 1.5$, dorsal view. 7, carapace, holotype (KMNH IVP 300,011), $\times 2.0$, dorsal view. 8, carapace, Noda collection (N676), $\times 2.0$, dorsal view.

outline, the length is about 0.75 of the width. The finely granulated dorsal surface is moderately convex. The regions are well defined. The epigastric lobes are transversely ridged. Broad, deep grooves separate the more convex protogastric lobes from the anterior mesogastric process and mesogastric lobes. The gently swollen mesogastric lobe is divided by a shallow median groove. The inflated urogastric lobe is well defined and there is a small boss between the urogastric and cardiac lobes. The cardiac region is hexagonal in outline; it is subdivided by a shallow median depression and there are two nodes transversely arranged. A deep cervical groove separates the flattened hepatic lobes from the branchial regions. The epibranchial lobes are strongly developed into ridges arching forwards and outwards to reach the last anterolateral tooth. The otherwise depressed meso- and metabranchial lobes become tumid surrounding the cardiac region. The orbito-frontal margin occupies about half of the carapace width. The frontal margin, separated from a small supraorbital angle by a shallow V-shaped notch, is composed of four blunt lobes; the inner pair, set close together to a V-shaped median sinus are separated by a U-shaped notch from the bluntly triangular outer pair. The concave upper orbital margin is pierced laterally by two deep fissures. Gently arched anterolateral margins have five well separated triangular teeth; the first four are directed forwards and the fifth laterally directed. Gently concave posterolateral margins are as long as the anterolateral margins.

Discussion.—A thin orbital margin, a long anterolateral margin and protogastric lobes without transverse ridges easily distinguish the present new species from *Portunites hexagonalis* Nagao, 1941 from the Late Eocene Poronai Formation of Hokkaido. *P. katta-chiensis* sp. nov. resembles *P. sylviae* Quayle and Collins, 1981 from the Eocene Barton Beds of England, but differs in having a wider carapace, large protogastric lobes and the fifth anterolateral tooth is strongly projected.

Repository.—KMNH IVP 300, 016 (Holotype); Noda collection (5927).

Superfamily Xanthoidea MacLeay, 1838
 Family Goneplacidae MacLeay, 1838
 Subfamily Carcinoplacinae
 H. Milne Edwards, 1852
 Genus *Branchioplax* Rathbun, 1916

Type species.—By monotypy *Branchioplax washingtoniana* Rathbun, 1916.

Geologic range.—Eocene to Oligocene.

Branchioplax pentagonalis
 (Yokoyama, 1911) comb. nov.

Figure 4-1; 5-4—6

Xanthilites pentagonalis Yokoyama, 1911, p. 13, pl. 3, fig. 3.

Carcinoplax sp., Tomita *et al.*, 1992, pl. 17, figs. 5-8.
Leucosia sp., Tomita *et al.*, 1992, pl. 17, fig. 9.

Diagnosis.—Carapace subquadrate, slightly wider than long; dorsal surface gently convex; regions well defined by shallow grooves; frontal margin straight with V-shaped median notch; orbital margin wide; anterolateral margin with five teeth. Chelipeds strongly heterochelate, covered with fine granules.

Description.—The carapace is subquadrate in outline and slightly wider than long. The finely granulated dorsal surface is gently convex. The regions are well defined by shallow grooves. The small epigastric lobes are gently raised transversely and the protogastric lobes are gently swollen and well separated from the slender anterior mesogastric process by rather deep grooves, whereas a boundary between the proto- and mesogastric lobes is indistinct. The flattened mesogastric lobe has two pairs of nodes on either side of the midline. The urogastric lobe is narrow and separated from the metabranchial lobes by deep epimeral adductor muscle scars. The cervical groove is conspicuous. There are three nodes set in an inverted triangle on the gently convex cardiac region. The flattened

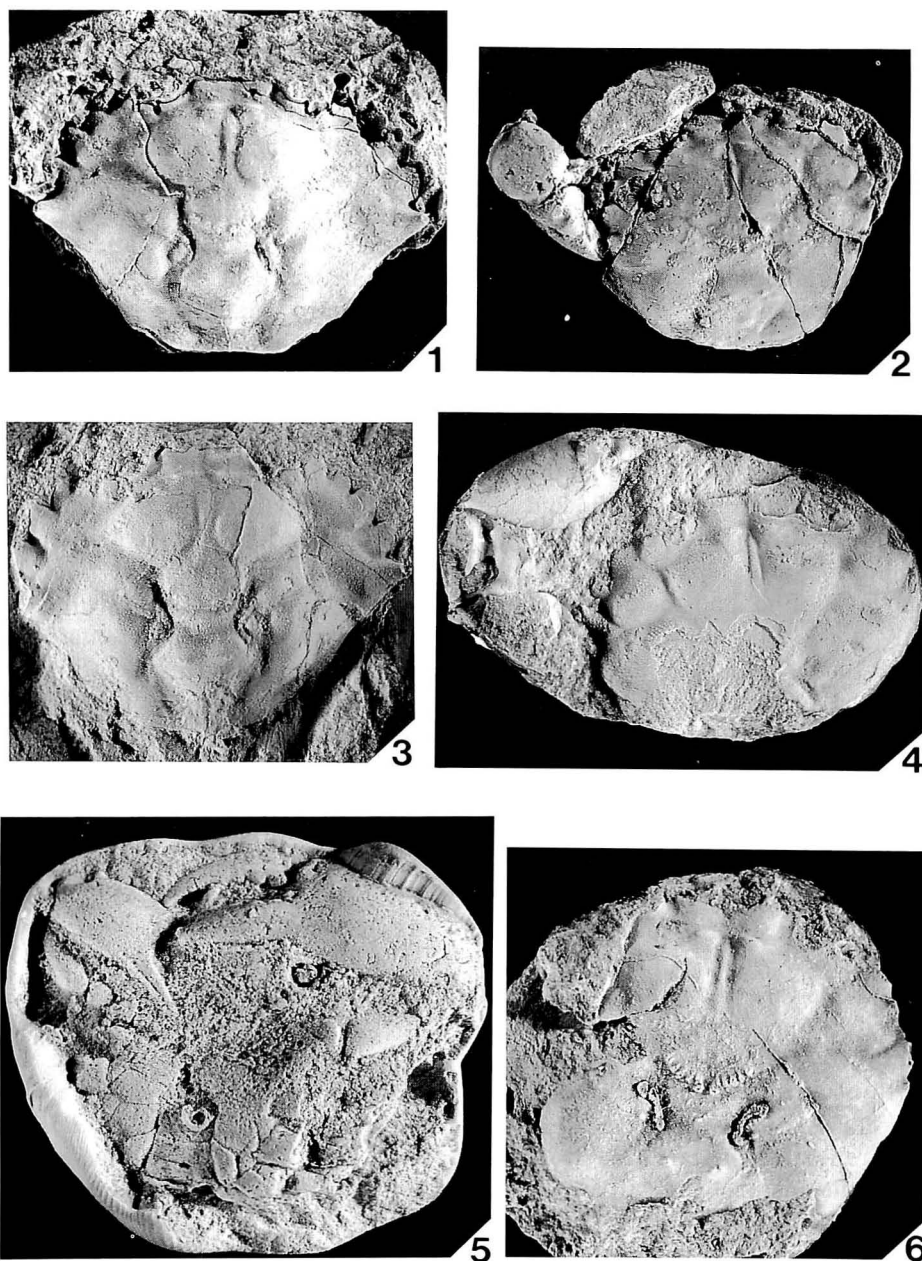


Figure 5. 1, 3, *Portunites kattachiensis* sp. nov. 1, carapace, $\times 2.0$, dorsal view, Noda collection (5927). 3, carapace, holotype (KMNH IVP 300,016), $\times 2.8$, dorsal view. 2, 4-6. *Branchioplax pentagonalis* (Yokoyama, 1911) comb. nov. 2, carapace and left cheliped, Noda collection (5927), $\times 1.2$, dorsal view. 4, carapace and left cheliped, KMNH IVP 300,018, $\times 1.5$, dorsal view. 5, left and right chelipeds, thoracic sterna and abdomen (plaster cast), KMNH IVP 300,019, $\times 1.5$, ventral view, 6, carapace, ESN 80005, $\times 2.0$, dorsal view.

intestinal lobe is small. Gently raised hepatic regions are well differentiated. The epibranchial lobes are gently swollen and arched anteriorly. The meso- and metabranchial lobes are also gently swollen. The orbitofrontal margin occupies 0.6–0.7 of the carapace width. The frontal margin is straight, divided medially by a V-shaped notch, and finely granulated, and a shallow sinus separates it from an obscure inner orbital angle. The upper orbital margin is wide and pierced by two shallow notches laterally. Gently arched anterolateral margins are 0.4 of the width; there are five teeth including the postorbital tooth; the 1st tooth is small and triangular in outline; the 2nd is the largest and broadly triangular in outline; the 3rd–5th are forwardly directed and acutely triangular in outline, and the 5th is smallest. Gently convex posterolateral margins are 1.2 times as long as the anterolateral margins and the posterior angle is broadly rounded into a slightly convex posterior margin.

Abdomen of male: The 7th somite is triangular in outline. The 6th, longest, is wider than long, with straight, parallel lateral margins. The 5th and 4th somites are also wider than long and their lateral margins taper anteriorly. The 3rd somite is narrow. The 2nd and 1st somites are not preserved.

Sternites 1 to 3 are missing and the 4th is broken; sternites 5 and 6 are wider than long; the 7th is narrower than the preceding two and the 8th is reduced in size.

The finely granulated chelipeds are strongly heterochelate, the major being rather more than half as long as the minor cheliped. The slender dactylus is gently curved ventrally and there seem to be four teeth diminishing in size distally on the occludent margin. The fixed finger is as long as the dactylus and possesses a longitudinal shallow groove on the ventrolateral surface. The palm is longer than the dactylus.

The pereopods are ovate in cross section.

Discussion.—Yokoyama (1911) originally

described this species on the basis of a single broken specimen obtained from a depth of 484 feet of a shaft at the Miike Coalfield. At that time, he considered the species to be most closely allied to *Xanthilites bowerbankii* Bell, 1858 from the Eocene of the Isle of Sheppey, England. Examination of a recently obtained well-preserved carapace, remaining associated chelipeds, thoracic sterna and a fragmentary abdomen indicate that this species should be transferred from *Xanthilites* Bell, 1858 to *Branchioplax* Rathbun, 1916. *B. pentagonalis* closely resembles *B. washingtoniana* Rathbun, 1916 from the Eocene of Alaska (Rathbun, 1926; Tucker and Feldmann, 1989), but differs in having a longer carapace and a finely granulated frontal margin which is separated from an obscure inner orbital angle by a shallow sinus. A longer carapace and five anterolateral teeth readily distinguish *B. pentagonalis* from *B. concinna* Quayle and Collins, 1981 from the Eocene Barton Clay of England. *B. pentagonalis* differs from *B. sulcata* Müller and Collins, 1991 from the Late Eocene Szépvölgy Formation of Hungary by having well defined dorsal regions of the carapace.

Repository.—KMNH IVP 300, 017–300, 019; ESN80005; Noda collection (5927).

Discussion

The Middle Eocene decapod fauna from the Manda Group is represented by five species; four species, *Callianassa muratai* Nagao, 1932, *C. elongatodigitata* Nagao, 1941, *Ranidina teshimai* Fujiyama and Takeda, 1980, and *Portunites hexagonalis* Nagao, 1941 have been described from the Late Eocene Poronai Formation of Hokkaido. Except for *Portunites*, decapods of the Manda Group have nothing in common with those of the Poronai Formation. In addition, the raninids are represented by different genera.

Both *Eucalliax* and *Raninoides* have living species, while *Prohomola*, *Portunites* and

Branchioplax are restricted to the Palaeogene. Whereas the fossil species of *Eucalliax* and *Prohomola* are endemic, those of *Raninoides*, *Portunites* and *Branchioplax* are recorded from the Palaeogene of North America, Central America, Senegal, England and Hungary (Rathbun, 1926; van Straelen, 1933; Remy and Tessier, 1954; Quayle and Collins, 1981; Müller and Collins, 1991). Accordingly, the occurrences of *Raninoides*, *Portunites* and *Branchioplax* show that the decapod fauna from the Middle Eocene Manda Group is related to the western and central Tethyan realms.

References cited

- Bell, T., 1858: *A monograph of the fossil malacostracous Crustacea of Great Britain. Part I, Crustacea of the London Clay.* 44 p., 11 pls. Palaeontographical Society, London.
- , 1863: *A monograph of the fossil malacostracous Crustacea of Great Britain. Part II, Crustacea of the Gault and Greensand.* 40 p., 11 pls. Palaeontographical Society, London.
- Biffar, T.A., 1970: Three new species of callianassid shrimp (Decapoda, Thalassinidea) from the western Atlantic. *Proc. Biol. Soc. Washington*, vol. 83, no. 3, p. 35–49.
- Bishop, G.A., 1983: Two new species of crabs, *Notopocorystes (Eucorystes) eichhorni* and *Zygastrocarcinus griesi* (Decapoda: Brachyura) from the Bearpaw Shale (Campanian) of North-Central America. *Jour. Paleont.*, vol. 57, no. 5, p. 900–911.
- , and Brannen, N.A., 1992: *Homolopsis pikeae*, new species (Decapoda), a crab from the Cretaceous of Texas. *Jour. Crustacean Biol.*, vol. 12, no. 2, p. 317–323.
- Fujiyama, I. and Takeda, M., 1980: A fossil raninid crab from the Poronai Formation, Hokkaido, Japan. *Professor Saburo Kanno Memorial Volume*, p. 339–342, pls. 39, 40. Tsukuba.
- Guinot, D. and Forges, B.R. de, (in press): Crustacea decapoda: La famille des Homolidae de Haan, 1839. In, A. Crosnier, ed., *Résultats des Campagnes MUSORSTOM, Mém. Mus. natn. Hist. nat., Paris.*
- Haan, W. de., 1833–1850: Crustacea. In, von Siebold, P.F., *Fauna Japonica sive Descriptio Animalium, quae in Iitnere per Japoniam, Jussu et Auspiciis Superiosum, qui Summum in India Batava Imperium Tenent, Suscepto, Annis 1823–1830 Collegit, Notis, Observationibus et Adumbrationibus Illustravit.* i–xvii, i–xxxii, ix–xvi + 243 p., pls A–J, L–Q, 1–55. Lugduni-Batavorum, Leiden.
- Jenkins, R.J.F., 1977: A new fossil homolid crab (Decapoda, Brachyura), Middle Tertiary, south-eastern Australia. *Trans. Roy. Soc. South Australia*, vol. 101, p. 1–10.
- Latreille, P.A., 1825: Entomologie, ou histoire naturelle des crustacés, des arachnides et des insectes. *Genre de Crustacés Encyclopédie Méthodique, Histoire Naturelle*, vol. 10, 832 p. Paris.
- Manning, R.B. and Felder, D.L., 1991: Revision of the American Callianassidae (Crustacea: Decapoda: Thalassinidea). *Proc. Biol. Soc. Washington*, vol. 104, no. 4, p. 764–792.
- Matsushita, H., 1949: A summary of the Palaeogene stratigraphy of northern Kyushu. *Mem. Fac. Sci. Kyushu Univ., ser. D*, vol. 2, p. 91–107.
- Milne Edwards, H., 1837: *Histoire naturelle des Crustacés, comprenant l'anatomie, la physiologie et la classification de ces animaux.* vol. 2, 532 p. Paris.
- , 1852: De la famille des ocypodides (Ocypodidae). Second Memoire. Observations sur les affinités zoologiques et la classification naturelle des Crustacés. *Ann. Sci. Nat., ser. 3 (Zool.)*, vol. 18, p. 128–166, pls. 3, 4. Paris.
- Mizuno, A., 1962: Paleogene and Lower Neogene biochronology of West Japan. Part II. *Jour. Geol. Soc. Japan*, vol. 68, p. 687–693. (in Japanese with English abstract)
- , 1963: Paleogene and Lower Neogene biochronology of West Japan. Part III. *Jour. Geol. Soc. Japan*, vol. 69, p. 38–50. (in Japanese with English abstract)
- , 1964: Paleogene and Early Neogene molluscan faunas in West Japan. *Rep. Geol. Surv. Japan*, no. 204, p. 72 p.
- , 1992: Reexamination of the biostratigraphic divisions, Mizuno, 1962–'63, for the Paleogene in western Kyushu, based on current age determination data. *Geol. Soc. Japan, Abstracts with Programs, 99th Ann. Meet.*, p. 179. (in Japanese)
- Müller, P. and Collins, J.S.H., 1991: Late Eocene coral associated decapods (Crustacea) from Hungary. *Contr. Tert. Quatern. Geol.*, vol. 28, nos. 2, 3, 47–92, 8 pls.
- Nagao, T., 1926: Palaeogene stratigraphy of Kyushu, Japan. Part 6. *Japan. Jour. Geol. Geogr.*, no. 452, p. 596–601. (in Japanese)
- , 1928: Palaeogene fossils of the Island of Kyushu, Japan. I. *Sci. Rep., Tohoku Imp. Univ., ser. 2*, vol. 9, no. 3, p. 97–128, pls. 17–22.
- , 1932: Two Tertiary and one Cretaceous Crustacea from Hokkaido, Japan. *Jour. Fac. Sci.*

- Hokkaido Univ., ser. 4, vol. 2, no. 1, p. 15-22, pl. 4.
- , 1941: On some fossil Crustacea from Japan. *Jour. Fac. Sci., Hokkaido Univ., ser. 4*, vol. 6, nos. 1, 2, p. 86-100, pl. 26.
- Ozaki, M. and Hamasaki, S., 1991: Fission track ages of the Paleogene strata in the northern part of Fukuoka Prefecture, Southwest Japan. *Jour. Geol. Soc. Japan*, vol. 97, no. 3, p. 251-254. (in Japanese)
- Parisi, B., 1915: I Decapodi giapponesi del Museo di Milano. II. Dromiacea. *Atti Soc. ital. Sci. nat.*, vol. 54, p. 102-116, pls. 2, 3.
- Quayle, W.J. and Collins, J.S.H., 1981: New Eocene crabs from the Hampshire basin. *Palaeontology*, vol. 24, no. 4, p. 733-758, pls. 104, 105.
- Remy, J.M. and Tessier, F., 1954: Décapodes nouveaux de la partie ouest du Sénégal. *Bull. Soc. géol. France, ser. 6*, vol. 4, p. 185-191, pl. 11.
- Rathbun, M.J., 1916: Description of a new genus and species of fossil crab from Port Townsend, Washington. *Amer. Jour. Sci.*, vol. 41, p. 344-346.
- Rathbun, M.J., 1926: The fossil stalk-eyed Crustacea of the Pacific slope of North America. *U. S. Nat. Mus., Bull.*, no. 138, 155 p, 39 pls.
- Straelen, V. van, 1933: Sur des crustacés décapodes cénozoïques du Venezuela. *Bull. Musée royal d'Hist. nat. Belgique*. vol. 9, no. 10, p. 1-14.
- Tomita, S., Ishibashi, T. and Hara, M., 1992: A brief note on the Paleogene of the Miike Coalfield in the Omuta district, Middle Kyushu, Japan. *Sci. Rep., Dep. Earth Planet. Sci., Kyushu Univ.*, vol. 17, no. 2, p. 25-43, pls 2-18. (in Japanese with English abstract)
- Tucker, A.B. and Feldmann, R.M., 1990: Fossil decapod crustaceans from the Lower Tertiary of the Prince William Sound region, Gulf of Alaska. *Jour. Paleont.*, vol. 63, no. 3, p. 409-427.
- Wood-Mason, J. and Alcock, A., 1891: Note on the results of the last season's deep-sea dredging: natural history notes from H.M. Indian Marine Survey Steamer 'Investigator,' Commander R.F. Hoskyn, R. N., Commanding, no. 21. *Ann. Mag. Nat. Hist., ser. 6*, vol. 7, p. 258-272.
- Yabumoto, Y. 1989. A new Eocene lamnoid shark, *Carcharodon nodai*, from Omuta in Northern Kyushu, Japan. *Bull. Kitakyushu Mus. Nat. Hist.*, no. 9, p. 111-116, pl. 1.
- Yokoyama, M. 1911. Some Tertiary fossils from the Miike coalfield. *Jour. Coll. Sci., Imp. Univ. Tokyo*, vol. 27, p. 1-16, 3 pls.

万田層群産中期始新世十脚甲殻類：福岡県大牟田市勝立に分布する中部始新統（沖ノ島階）万田層群勝立層より産した3新種を含む5種の十脚甲殻類化石を記載する。それらは、*Eucalliax yoshihiro* sp. nov. (スナモグリ科), *Prohomola japonica* (Yokoyama) gen. nov. (ホモラ科), *Raninoides nodai* sp. nov. (アサヒガニ科), *Portunites kattachiensis* sp. nov. (ガザミ科), *Branchioplax pentagonalis* (Yokoyama) comb. nov. (エンコウガニ科) である。*Raninoides*, *Portunites*, *Branchioplax* 属の存在は、万田層群の十脚甲殻類ファウナが、古生物地理上、始新世における西部・中部テーチス地域の十脚甲殻類ファウナと関連があったことを示す。

柄沢宏明

SHORT NOTES

29. *PSEUDOSCHWAGERINA SKINNERI*, N. SP. FROM NEAR KAMLOOPS
IN BRITISH COLUMBIA, CANADA*

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Carboniferous and Permian limestones ranging in age from late Early Carboniferous to Middle Permian crop out in the Kamloops area of British Columbia in Canada. The Permian fusulinacean faunas in the limestones in this area have been reported by

several workers (Thompson and Verville, 1950; Skinner and Wilde, 1966; Danner, 1970a, 1970b; Sada and Danner, 1974, 1976, 1989).

An Early Permian *Pseudoschwagerina* fauna was described by Sada and Danner in

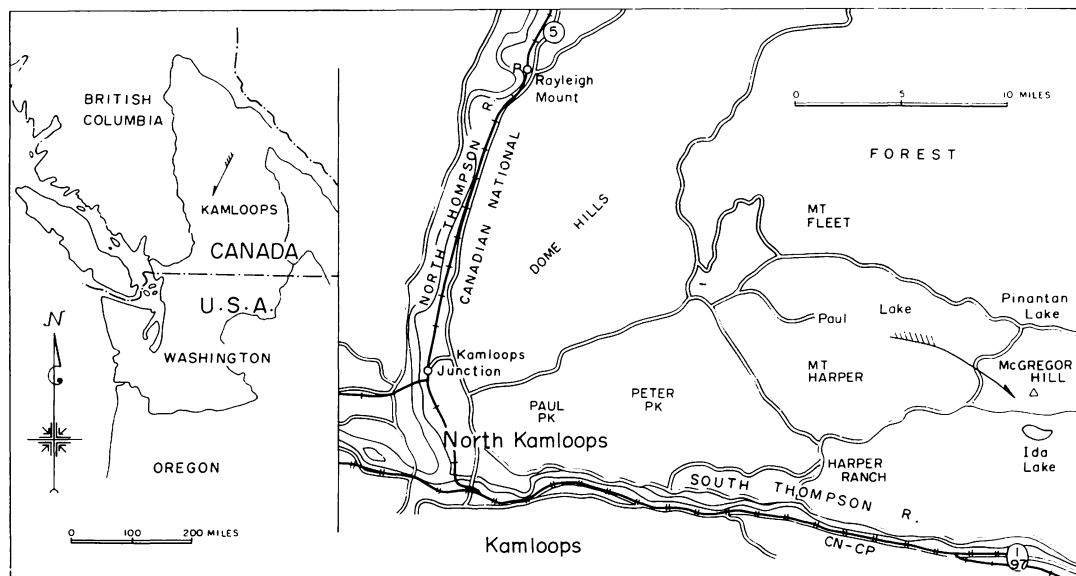


Figure 1. Map showing the fossil locality in the Ida Lake area (southwest side of McGregor Hill), near Harper Ranch northeast of Kamloops in British Columbia.

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1976 from Harper Ranch northeast of Kamloops in British Columbia and included species *Pseudoschwagerina robusta* (Meek) and *P. sp. A* (Sada and Danner, 1976, p. 217-224, pl. 1, figs. 1-2, pl. 2, figs. 1-2). The Harper Ranch *Pseudoschwagerina* fauna was correlated with the middle Wolfcampian *Pseudoschwagerina* fauna of Zone E in the McCloud Limestone in California (Skinner and Wilde, 1965).

At this time we describe the unusual species of *Pseudoschwagerina* offered by the late Dr. John W. Skinner in 1977, which had originally been collected by Danner from limestones cropping out in the Ida Lake area near Harper Ranch northeast of Kamloops. This

species is described herein as *Pseudoschwagerina skinneri*, n. sp.

Description of species

Subfamily Schwagerininae Dunbar and Henbest, 1930

Genus *Pseudoschwagerina* Dunbar and Skinner, 1936

Type species.—*Schwagerina uddeni* Beede and Kniker, 1924

Pseudoschwagerina skinneri, n. sp.

Figures 2-1-2, 3-1

Holotype.—UHBHHR-1 (Figure 2-1)

Description.—The shell of *Pseudoschwagerina skinneri*, n. sp. is large and very highly inflated fusiform with a straight axis of coiling and bluntly pointed poles. The lateral slopes are slightly convex. The shell of the holotype (Figure 2-1) is 15.25 mm. in length and 10.00 mm. in width, giving a form ratio of 1.52. The proloculus is large and spherical and its diameter ranges from 0.30 to 0.50 mm. The shell is coiled tightly in the inner two volutions and beyond the third volution expands rapidly. The radius vectors of the first to the seventh volutions in a specimen illustrated as Figure 2-1 are 0.50, 0.80, 1.75, 2.70, 3.55, 4.35 and 5.00 mm., respectively. The chamber height is almost the same throughout the length of the shell except the extreme polar regions.

The spirotheca is composed of a tectum and coarsely alveolar keriotheca. The spirothecal thickness of the holotype in the first to the seventh volutions is 75, 56, 56, 75, 113, 132, and 94 μ m, respectively.

The septa are closely spaced in the first two volutions and in the third to the last volutions the septa are more widely spaced. They are fluted in the basal margins and extreme polar areas. The chomata are very small in the inner volutions and indistinct in the outer volutions.

Remarks.—It appears that the present

Table 1. Measurements of *Pseudoschwagerina skinneri*, n. sp. (mm.)

Specimen	UHBHHR-1	UHBHHR-2
Figure	1-1	1-2
Length	15.25	16.25
Width	10.00	10.05
F.R.	1.52	1.61
Prol.	0.40	0.30
	0.50	0.35
Radius vector		
Vol.		
1	0.50	0.25
2	0.80	0.65
3	1.75	1.40
4	2.70	2.75
5	3.55	3.75
6	4.35	4.55
7	5.00	5.25
Thickness of spirotheca		
0	0.075	0.056
1	0.075	0.037
2	0.056	0.037
3	0.056	0.037
4	0.075	0.056
5	0.113	0.075
6	0.132	0.113
7	0.094	0.151

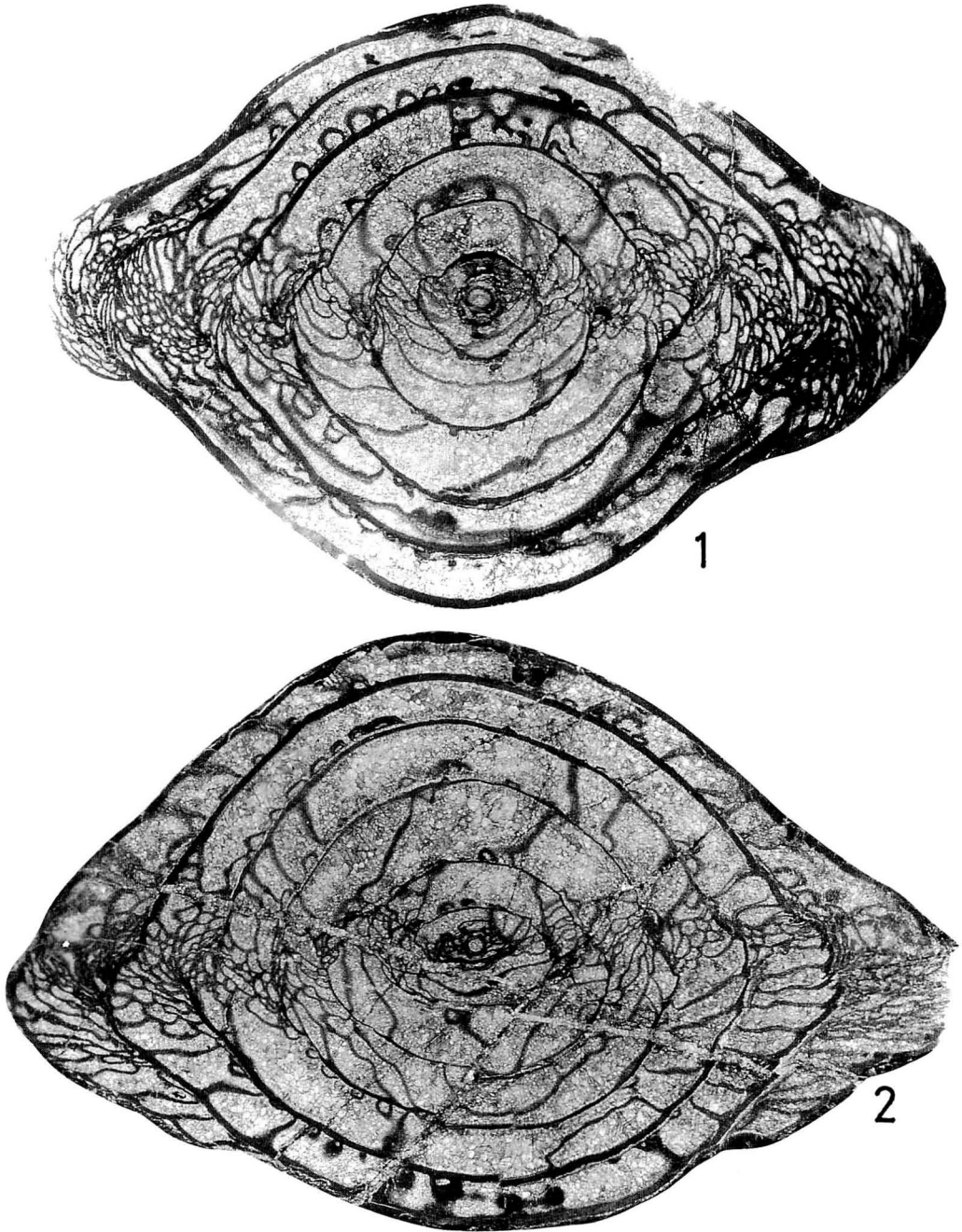


Figure 2. *Pseudoschwagerina skinneri*, n. sp. 1, axial section, holotype, UHBHHR-1, $\times 10$. 2, axial section, paratype, UHBHHR-2, $\times 10$.

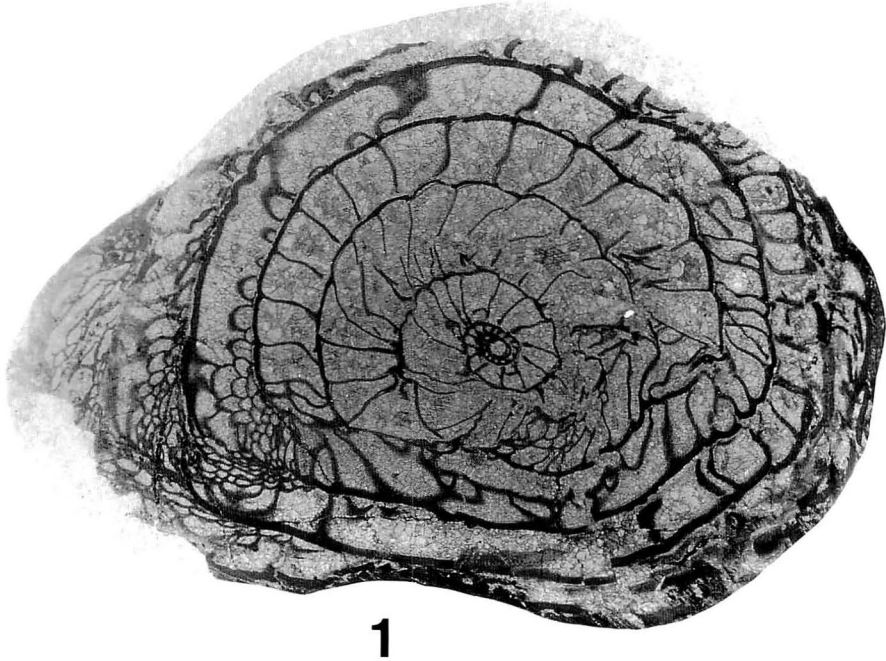


Figure 3. *Pseudoschwagerina skinneri*, n. sp. 1, sagittal section, paratype, UHBHHR-3, $\times 10$.

species is somewhat similar to the genus *Robustoschwagerina* in the size of the shell. However, it has not the globular nor the strongly umbilicated shell. It is robustly fusiform in shell shape and has a large proloculus. The inner two volutions are tightly coiled and the outer ones are highly and strongly inflated. From this evidence, the present species can be referred to the genus *Pseudoschwagerina*.

In 1976 we reported *Pseudoschwagerina* sp. A associated with *Pseudoschwagerina robusta* (Meek), *Eoparafusulina* and corals from the Harper Ranch area near Kamloops in British Columbia. The present species somewhat resembles *Pseudoschwagerina* sp. A (Sada and Danner, 1976, p. 220, pl. 2, figs. 1-2). The former species, however, is distinguished from the latter by its larger shell, larger proloculus, and more rapid expansion of the shell.

The present species is somewhat similar to *Pseudoschwagerina robusta* (Meek) described by Skinner and Wilde (1965, p. 71-72, pl. 32,

figs. 14, pl. 33, figs. 1-6) and by Sada and Danner (1976, p. 217-219, pl. 1, figs. 1-2) in general outline of the shell. However, the former species differs from the latter in having a larger shell and greater numbers of volutions.

The present species is different from any of the other known species of *Pseudoschwagerina* by its remarkable shell.

Locality.—Material came from the southwest side of large limestone knob (McGregor Hill) just north of Ida Lake and south of Pinantan Lake located northeast of Kamloops.

References

- Danner, W.R., 1970a: Carboniferous system of the western Cordillera of southeastern British Columbia and northwestern Washington. *Compte Rendu, 6th Congress Internat. Strat. Geol. Carbonif.*, vol. 2, p. 599-608.
- , 1970b: Paleontologic and stratigraphic evidence for and against sea floor spreading and opening and closing oceans in the Pacific North-

- west. *Geol. Soc. Amer., Abstracts with Program*, vol. 2, no. 2, p. 84-85.
- Sada, K. and Danner, W.R., 1974: Early and middle Pennsylvanian fusulinids from southern British Columbia, Canada and northwestern Washington, U.S.A. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 93, p. 249-265, pls. 35-37.
- , and Danner, W.R., 1976: *Pseudoschwagerina* from Harper Ranch area near Kamloops, British Columbia, Canada. *Com. Vol. Found. Fac. Integr. Arts and Sci., Hiroshima Univ.*, p. 213-228, pls. 1-2.
- , and Danner, W.R., 1989: *Pseudoschwagerina* sp. (n. sp.) from Kamloops area in British Columbia, Canada. *Palaeont. Soc. Japan, Abstracts with Programs, 138th Regular Meet.*, p. 41.
- Skinner, J.W., and Wilde, G.L., 1965: Permian biostratigraphy and fusulinid faunas of the Shasta Lake area, northern California. *Univ. Kansas, Paleont. Contr.*, no. 39 (Protozoa, art. 6), p. 1-98, pls. 1-65.
- , and Wilde, G.L., 1966: A new Permian fusulinid from southern British Columbia, Canada. *Acad. Sci. U.S.S.R., Prob. Micropaleont.*, no. 10, p. 105-108, pls. 1-2. (in Russian)
- Thompson, M.L., and Verville, G.J., 1950: Cache Creek fusulinids from Kamloops, British Columbia. *Contr. Cushman Found. Foram. Res.*, vol. 1, p. 67-70, pl. 8.

PROCEEDINGS OF THE PALAEOLOGICAL
SOCIETY OF JAPAN

Palaeontological Society of Japan (PSJ) Council Actions

During its meeting on June 20, 1992, the PSJ Council enacted the following changes to its membership.

New members elected :

Hitoshi Furusawa,	Hajime Honma,	Yasuaki Isomura,
Norio Kito,	Yolanda O. Maac,	Nobuo Majima,
Naoko Nikkawa,	Shinichi Nishinosono,	Akira Okajima,
Takayoshi Okajima,	Kenichi Okushi,	Shinji Satou,
Hiroshi Sawamura,	Yayoi Shinada,	Tatsuya Takahashi,
Georg Waldmann.		

New patron members ;

The Kiseki Museum of World Stones,
Social Education Division, Itoigawa Municipal Board of Education.

Resigned members ;

(Fellow)

Kazuo Ohmura

(Ordinary members)

Sumito Mizushima,

Tsutomu Utashiro,

Jean Vannier,

Noriko Nakazato.

行事予定

◎1993年年会・総会は、1993年1月29日、30日、31日に筑波大学で開催されます。講演申込は12月10日(必着)締切です。講演申込の方法が変更になっています。詳しくは「化石」48号をご覧ください。

◎1993年例会(第142回例会)は、大阪教育大学で6月後半に開催の予定です。

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