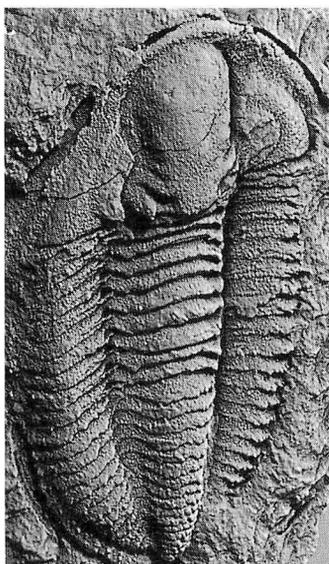


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The fossil on the cover is *Phillipsia ohmorensis* Okubo, an Early Carboniferous trilobite from the Hikoroichi Formation in the Higuchizawa valley, Ofunato City, Iwate Prefecture, northeast Japan (Collected by A. Haga, PAt 5766, $\times 3.0$; after Kobayashi and Hamada, 1980, pl. 6, fig. 4).

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903. TAXONOMIC AND PALEOZOOGEOGRAPHIC SIGNIFICANCE OF CENOZOIC HUNCH-BACK LIKE VENERIDS

PART 1. *GIGANTOCALLISTA*, GEN. NOV. (MOLLUSCA : BIVALVIA),
A NEW ENDEMIC VENERID GENUS FROM THE PLIOCENE
TATSUNOKUCHI FORMATION, SENDAI CITY,
MIYAGI PREFECTURE, NORTHEASTERN JAPAN*

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Abstract. A new genus of hunch-back like Bivalvia, *Gigantocallista*, is proposed and *Pitar sendaica* Nomura is designated as the type-species. The genus is monotypic and may have evolved from the Miocene genus *Neogenella*. *Gigantocallista sendaica* occurs only in the Pliocene Tatsunokuchi Formation, and may reflect localized zoogeographic or paleoecological conditions within the Pliocene Paleo-Sendai Bay.

Key words. Hunch-back like shell, *Gigantocallista*, Tatsunokuchi Formation, Tatsunokuchi Fauna, Pliocene.

Introduction

The extraordinary group of *Pitar* (Hayasaka and Uozumi, 1954), or "the so-called Tertiary *Pitar*" (Iwasaki, 1963) is a venerid with an unusually thick hunch-back like shell. In Japan, *Pitar okadana* (Yokoyama), *P. itoi* Makiyama, *P. hokkaidoensis* Nomura, and *P. sendaica* Nomura have been included in this above-mentioned "*Pitar*" group (Iwasaki, 1963). This group of *Pitar* has long been well known from Miocene and Pliocene deposits of Japan, Korea, Sakhalin and Kamchatka. Particular attention has been paid to this type of *Pitar* because of its biostratigraphic value as well as its unusual morphology (Makiyama, 1926, 1936; Yokoyama, 1932; Nomura, 1935, 1938, 1940; Slodkewitsch, 1938; Nomura and Hatai, 1936, 1937; Uozumi, 1953, 1962; Hayasaka

and Uozumi, 1954; Tanaka, 1961; Iwasaki, 1963; Iwai, 1965; Masuda, 1966; Zhidkova *et al.*, 1968, 1972; Itoigawa, *et al.*, 1974; Itoigawa *et al.*, 1981a, b; Amano, 1983, 1986; Gladenkov, 1984; Menner, 1984).

Though this type of venerid has long been included in *Pitar*, its dentition is clearly different from *Pitar* Römer (Iwasaki, 1963). The taxonomic position of this venerid has not been settled to many authors yet, who either include the above-mentioned "*Pitar*" species in Römer's *Pitar*, or in *Pseudamiantis* Kuroda (1933). Krishtofovich (1955, *vide* Zhidkova *et al.*, 1968) proposed *Neogenella* as a subgenus of *Pitar* Römer and some authors included this type of "*Pitar*" in his subgenus. But as already mentioned by Iwasaki (1963), its dentition is not of *Pitar*-type, so this type of "*Pitar*" should not be included in the genus *Pitar*.

These so-called *Pitar* species are biogeographically significant. They and their allied

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species are known only in eastern Asia, although significant changes in their geographic distribution have occurred during the Neogene. In Miocene time they inhabited Korea, Honshu, Hokkaido, Sakhalin and western Kamchatka, but in Pliocene time they were confined only to Sendai Basin (Takagi, 1987, 1989 MS).

The present writer was recently given the opportunity to re-examine the extraordinary group of *Pitar* from the Miocene and the Pliocene deposits of various localities in Hokkaido, Honshu, Korea, and western Kamchatka. He proposed a new genus, *Gigantocallista*, based upon *Pitar sendaica* Nomura (1938) and included Miocene species, *P. okadana*, *P. itoi*, and *P. hokkaidoensis* in the genus *Neogenella* Krifstovich.

In this paper, the writer discusses the taxonomic and paleozoogeographic positions of the new genus *Gigantocallista*. The taxonomic and paleozoogeographic problems of *Neogenella* will be discussed in another paper.

Systematic description

Order Veneroida H. and A. Adams, 1858

Superfamily Veneracea Rafinesque, 1815

Family Veneridae Rafinesque, 1815

Genus *Gigantocallista* Takagi, gen. nov.

Type species.—*Pitar sendaica* Nomura, 1938, by original designation. Pliocene Tansunokuchi Formation, Sendai, Miyagi Prefecture, Japan.

Diagnosis.—Hunch-back like *Callista*-type genus with high and strong hinge plate, peculiar cardinals and laterals; *Neogenella*-like cardinals in right valve and Δ -shape strong cardinals of (2a)-(2b), and remarkably large and heavy lateral in left valve.

Description.—Shell large, test thick, trigonalovate, strongly inflated; lunule wide, cordate, obscurely impressed; escutcheon indistinct; sculpture consisting of incremental

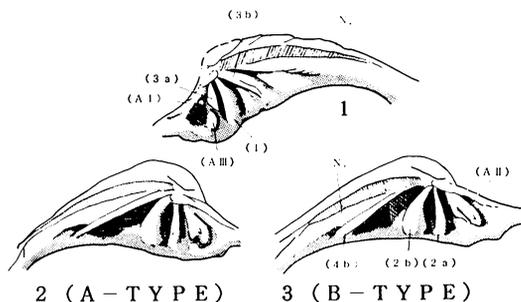


Figure 1. Hinge area of *Gigantocallista*. 1: right valve; (1): middle cardinal, (3a): anterior cardinal, (3b): posterior cardinal, (AI) and (AIII): anterior lateral lamellae, N.: nymph. 2-3: left valve; (2a): anterior cardinal, (2b): middle cardinal, (4b): posterior cardinal, (AII): anterior lateral. Hinge of right valve: consisting of 3 cardinals and two anterior laterals; the anterior (3a) and middle (1) cardinals almost perpendicular to the hinge margin, middle (1) one heavy; the anterior (3a) one short, posterior (3b) one bifid, anterior lateral lamellae (AI) and (AIII) indistinct and flanking a deep socket, (AII) almost parallel to middle (1), cardinal. Hinge of left valve: consisting of 3 cardinals and one anterior lateral; anterior (2a) one rather thin; the middle (2b) one very heavy, posterior (4b) one slender and almost joined to the nymph, anterior (2a) narrowly continuing to middle (2b) one and making Δ -shape, anterior lateral (AII) heavy, conical, and bifid, the base of (AII) extending toward the beak. The type species of *Gigantocallista*, *G. sendaica* exhibits dimorphism in anterior lateral (AII); most of specimens have large thickened and strongly inflated anterior lateral AII (A-type), but one specimen, large but thinner than A-type and distinctly bifid one (B-type).

growth lines and very weak radial striae; hinge plate high, thick; hinge of right valve consisting of 2 indistinct anterior lateral lamellae (AI and AIII) flanking a deep socket, and strong 3 cardinals, the anterior (3a) and middle (1) ones almost perpendicular to hinge margin, the middle (1) one heavy, the anterior (3a) one short, the posterior one bifid; hinge of left valve consisting of a heavy, conical, bifid anterior lateral (AII) and 3 cardinals, the anterior one (2a) rather thin, the middle one (2b) very heavy, the posterior one (4b) slender and almost joined to nymph, the base of AII extending toward beak; pal-

lial sinus deep; ventral margin smooth.

Comparison.—*Gigantocallista*, gen. nov. differs from all other venerid genera in possessing a high and strong hinge plate, and peculiar cardinals and laterals; *Neogenella*-like cardinals in right valve, Λ -shaped strong cardinals of (2a)-(2b), and a remarkably large and heavy lateral in the left valve (Figure 1). Above mentioned dentition of *Gigantocallista* is dissimilar to that of *Pitar*, but of *Callista*.

Callista Poli (1791, *fide* Cox *et al.*, 1969) resembles the present genus by having Λ -shaped cardinals of (2a)-(2b) and beak-side stretched AII in the left valve, which are common characters of the subfamily *Callistinae* Nordsieck (1969; *fide* Cox *et al.*, 1969). However, the present genus differs from *Callista* in possessing a thin and less inflated shell, a lower and thinner hinge plate, and a smaller and thinner anterior lateral in the left valve.

Nomura (1938) applied the genus *Pitar* Römer (1857) to his new species *sendaica*, designated as *Gigantocallista* herein, because its teeth arrangement is of *Pitar* and its large and heavy shell may be placed in *Megapitaria*. However, at that time, he had only worn and imperfect specimens to examine. However, *Pitar* differs from *Gigantocallista* in possessing a low and thin hinge plate, bridged cardinals of (2a)-(2b) that are almost parallel to the hinge margin anterior lateral in the left valve. The subgenera of *Pitar*, *Pitarina* Jukes-Browne (1913, *fide* Cox *et al.*, 1969), *Lamelliconcha* Dall (1902) and *Hyphantosoma* Dall (1902), have similar dentition, but differ from *Gigantocallista*.

Hysterochoncha Dall (1902) and *Costelipitar* Habe (1951) also have *Pitar*-type dentition as mentioned above except for their posterior cardinal in left valve and can be easily distinguished from *Gigantocallista* by having low and thin hinge plate, and bridged cardinals of (2a)-(2b).

Nomura (1938) also discussed the relation of *Pitar sendaica* with *Megapitaria* Grant

and Gale (1931), and *Amiantis* Carpenter (1864, *fide* Grant and Gale, 1931). However, *Megapitaria*, which was raised from the subgenus of *Pitar* to generic rank by Hertlein and Grant (1972), differs from the present genus in possessing a thinner shell, a low and thinner hinge plate, bridged cardinals of (2a)-(2b), and a thinner anterior lateral in the left valve.

Amiantis resembles *Gigantocallista* in having large and heavy shell, but differs from the latter in possessing a low and thin hinge plate, a thin and short (3a) cardinal in its right valve, bridged cardinals of (2a)-(2b) and an isolated long anterior lateral in the left valve, that is almost parallel to hinge margin.

Macrocallista Meek (1876 *fide* Grant and Gale, 1931; Korobkov, 1954) resembles *Gigantocallista* in having a large shell and Λ -shaped cardinals of (2a)-(2b) in the left valve, but differs from the latter in possessing a thin and elongated shell, a low and thin hinge plate, and a thin anterior lateral in the left valve.

Ezocallista Kamada (1962) resembles the present genus in having a large shell, and Λ -shaped cardinals of (2a)-(2b) in its left valve, but differs from *Gigantocallista* in possessing independent cardinals of (2a) and (2b), and a thin anterior lateral in its left valve.

Saxidomus Conrad (1897, *fide* Grant and Gale, 1931) resembles the present genus in having rather distinct concentric lines on its surface, and Λ -shaped cardinals of (2a)-(2b) in the left valve, but differs from *Gigantocallista* in possessing a thin shell, a low and thin hinge plate, and an anterior denticle joined to (3a) cardinal in its right valve.

Pseudamiantis Kuroda (Kuroda, 1933; Iwasaki, 1963; Habe, 1977) resembles the present genus in having a large shell and similar dentition in the right valve. Chinzei and Iwasaki (1967) applied the generic name *Pseudamiantis* Kuroda (1933), without description or remarks, to the type-species of the present genus and some authors followed

them (e.g., Chinzei, 1978; Masuda, 1986; Matsui, 1988). But *Pseudamiantis* differs from *Gigantocallista* in possessing low and thinner hinge plate, bridged cardinals of (2a)-(2b), isolated (=not joined to nymph) (4b) cardinal in the left valve, distinct radial threads on the surface, and a thinner shell (Figure 7-5).

Neogenella Krishtofovich (1955, *vide* Zhidkova *et al.*, 1968) resembles *Gigantocallista* in having a high and thick hinge plate and a thick hunch-like shell. Amano (1983) included the type-species of the present genus in *Neogenella*, but it differs from the present genus in possessing bridged cardinals of (2a)-(2b) in the left valve, and large middle cardinals (1) and short anterior (3a) one in the right valve (Figures 6-5a-b and Figure 7-6).

Gigantocallista is represented only by the Pliocene *G. sendaica* (Nomura) from the Tatsunokuchi Formation in Miyagi Prefecture and may be restricted to the Pliocene Paleo-Sendai Bay (Chinzei and Iwasaki, 1967; Masuda and Ogasawara, 1981). From the peculiar hunch-back like shell, high and thick hinge plate, and similar dentition except

for anterior and middle cardinals in left valve, *Gigantocallista* may have evolved from the Miocene *Neogenella*. The relation of both genera with the taxonomic problem of

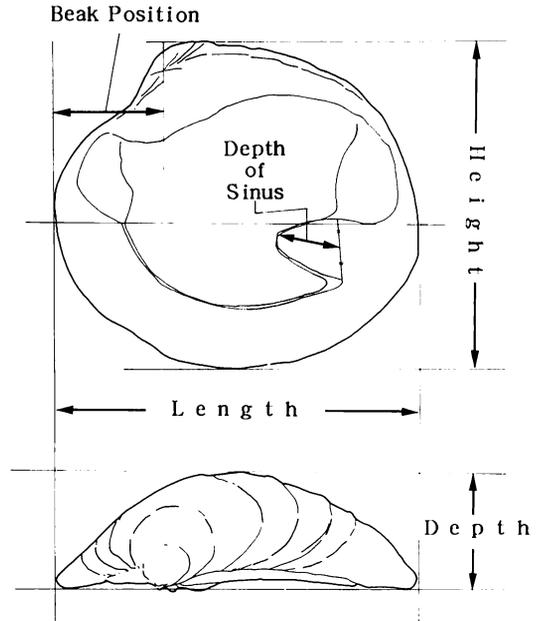


Figure 2. Measurement of *Gigantocallista sendaica*.

Table 1. Measurements (in mm) of *G. sendaica* from the Tatsunokuchi Formation. B.P.: Beak position (=distance anterior end to beak); Ds: depth of sinus; V: valve; R: right; L: left; CON: conjoined. Locality; Goroku: Gōroku Cliff, Sendai City; Sendai: unknown, but in Sendai City; Chuo-5: Chūō 5-chome, Sendai City. SHK: Saito Ho-on Kai Museum register number; UH: University of Hokkaido register number; * 1: Masuda's collection at Miyagi University of Education, * 2: single valve %.

No.	Loc.	Meg. No.	Length	Height	Depth	B.P.	Ds.	H/L%	D/H%*2	BP/L%	V.
Go-1	Goroku	SHK 4017	66.0	55.0	22.0	15.1	19.8	83.3	40.0	22.9	R
Go-2	Goroku	SHK 4017	96.0	78.0	33.0	22.4	—	81.3	42.3	23.3	L
Go-3	Goroku	SHK 4017	74.0	61.0	27.0	—	—	82.4	44.3	—	L
Go-4	Goroku	SHK 4017	69.0	57.0	25.0	—	—	82.6	43.9	—	R
Go-5	Goroku	SHKc16131	82.0	78.0	64.0/2	29.4	—	95.1	41.0	35.6	CON.
Go-6	Goroku	————*1	96.5	84.2	71.6/2	28.0	—	87.3	42.5	29.0	CON.
Go-7	Goroku	UH 31000	58.0	47.0	17.0	17.2	—	81.0	36.1	29.7	L
Go-8	Goroku	UH 31001	72.0	62.8	21.5	24.0	—	87.2	34.2	33.3	L
Go-9	Goroku	UH 31002	86.0	72.8	26.0	26.9	—	84.7	35.7	31.2	L
Se-1	Sendai	————*1	90.2	77.0	51.4/2	26.0	—	85.4	33.4	28.8	CON.
Cu-1	Chuo-5	UH 31003	96.0	90.0	28.9	26.8	21.5	93.8	32.1	27.9	R
Cu-2	Chuo-5	UH 31004	86.2	78.0	25.5	25.5	28.2	90.5	32.6	29.6	R
Cu-3	Chuo-5	UH 31005	81.6	76.6	27.9	26.0	20.0	93.9	36.4	31.9	L

Neogenella will be discussed in another paper.

Gigantocallista sendaica
(Nomura, 1938)

Figures 6-1—4b; 7-1—4

Pitar sendaica Nomura, 1938, p. 258, pl. 35(3), figs. 1-

3, 10a-b.

Pitar sendaica monstrosa Nomura, 1938, p. 259, pl. 35(3), figs. 8a-b, 9a-b.

Remarks: — The present writer re-examined the specimens of this species from the Tatsunokuchi Formation including Nomura's type specimens in the Saito Ho-on Kai Museum. Measured specimens are not

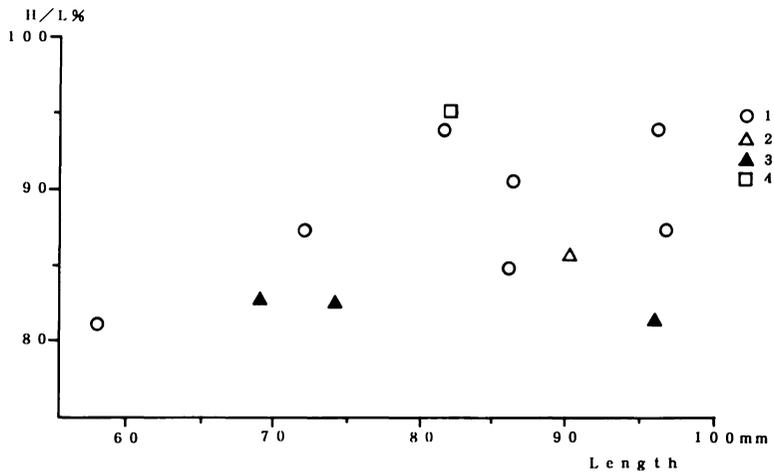


Figure 3. Relation between height/length and length of *Gigantocallista sendaica* (Nomura). H/L %: height/length %; 1: specimens from Gôroku Cliff, Sendai City; 2: specimens from Sendai City (locality unknown); 3: specimens from Chûô 5-chome, Sendai City; 4: type-specimen of *Pitar sendaica monstrosa* Nomura.

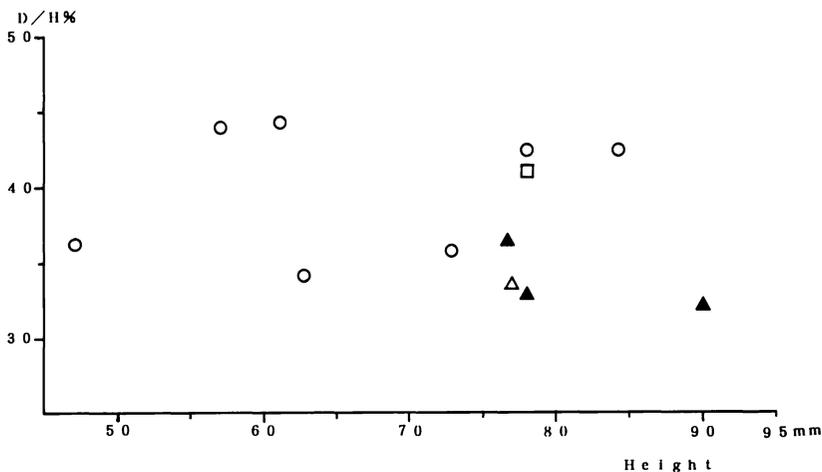


Figure 4. Relation between depth/height and height of *Gigantocallista sendaica* (Nomura). D/H %: depth/height %; symbols are the same as in Figure 3.

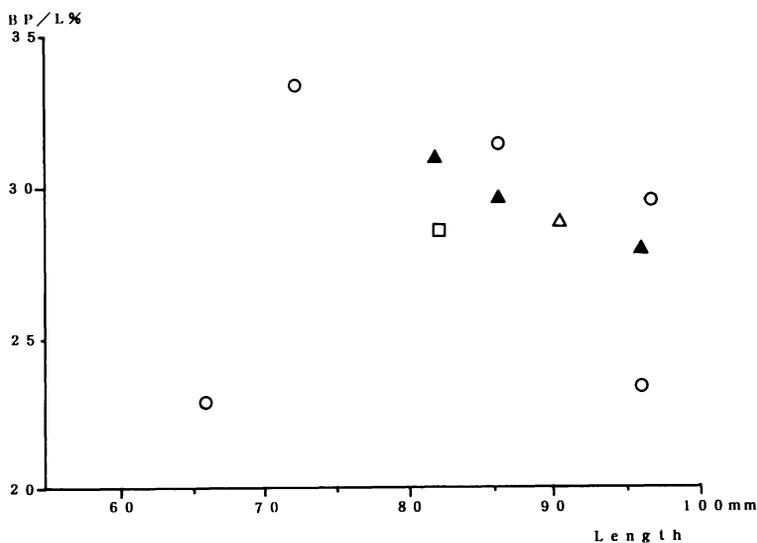
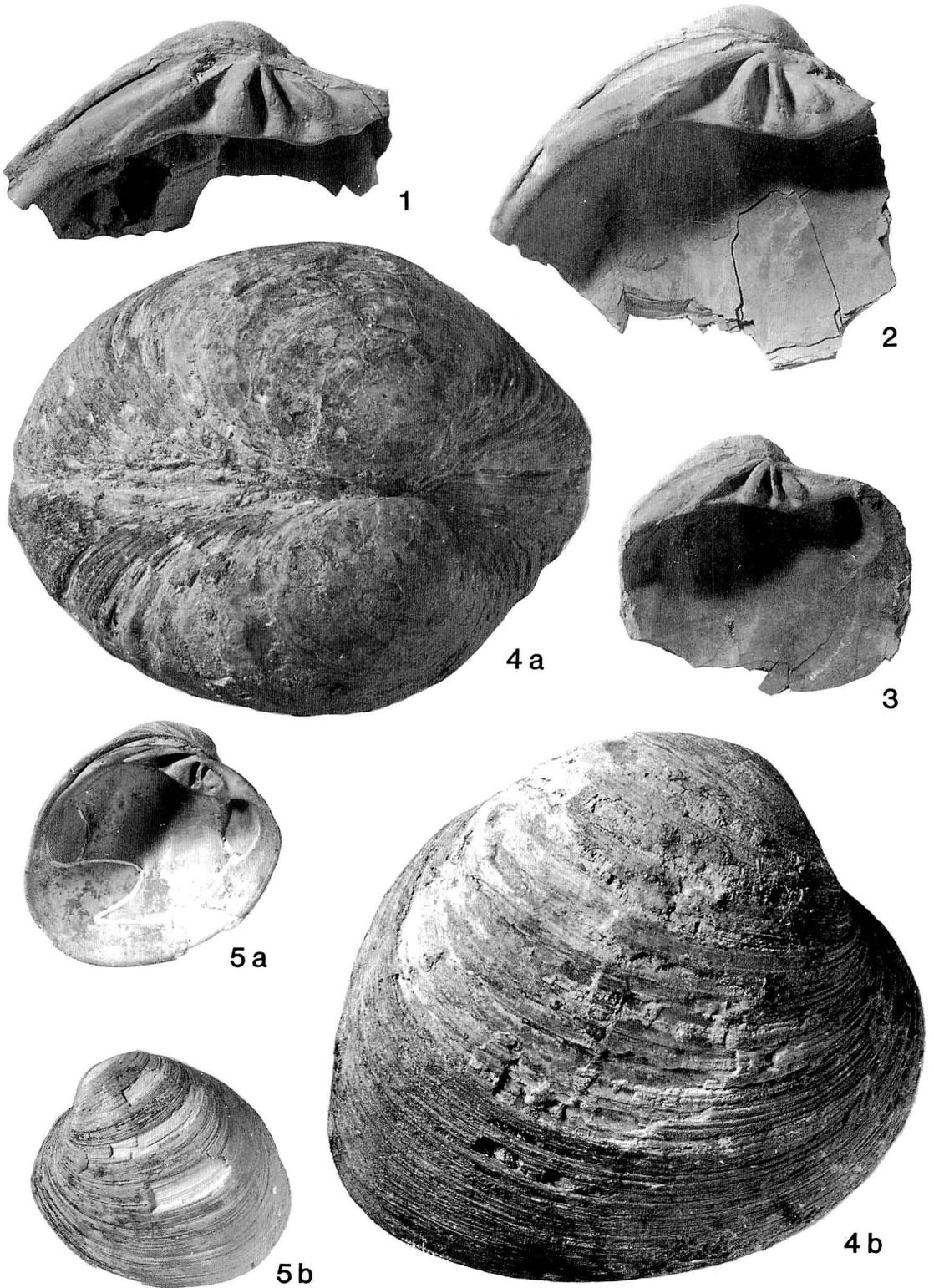


Figure 5. Relation between beak position (=distance from anterior end to beak)/length and length. BP/L % : beak position/length % ; symbols are the same as in Figure 3.

so many because most of materials at hand are imperfect. Statistically useful measured data, therefore, will be needed for discussing the strict variation of this species. Examining all material at hand, the writer recognized a variation of height/length ranging from 81% to 95% (Figure 3), and a variation of depth/height ranging from 32% to 44% (Figure 4). Generally speaking, the most common proportion is about 80-88% in the former, and in the latter, 32-38%, both being observed in both immature and adult shells. The present species exhibits dimorphism in the anterior lateral of the left valve (Figure 1). Most specimens have an A-type lateral, which is large, thickened and strongly inflated. But one specimen has a B-type lateral, which is large, but thinner than the A-type, and distinctly bifid. The B-type lateral may be abnormal form of this species.

Nomura (1938) described *Pitar sendaica monstrosa* based on specimens from the same locality as *Pitar sendaica*, and noted that this subspecies can be distinguished from *sendaica* (s.s) by "having more inflated valves, beaks placed slightly more anteriorly with a more convex, or somewhat hump-back curvature along the postero-dorsal border". But the type specimens of Nomura's *P. sendaica* (s.s) have more inflated shells (42.3-44.3% in depth/height) than those of *P. sendaica monstrosa* (41%), and the proportion of beak point/length of *Gigantocallista sendaica* from the Tatsunokuchi Formation grades continuously from 27.9% to 36.3% (Figure 5). Since they occur from the same place and can not be divided from each other by morphological characters, Nomura's *P. sendaica monstrosa* may be considered herein to be a junior synonym of *P. sendaica* (s.s). Similar

→ **Figures 6-1 — 4b.** *Gigantocallista sendaica* (Nomura) 1-3, hinge area of left valve, 1 : U.H. Reg. No. 31006, $\times 1.35$; 2 : U.H. Reg. No. 31007, $\times 1$; 3 : U.H. Reg. No. 31008, $\times 1$; 4a — b : dorsal (4a) and right (4b) views, Prof. Masuda's collection in Miyagi University of Education, $\times 1$; 1 — 3, Tatsunokuchi Formation, Chûô 5 chôme, Sendai City; 4, Tatsunokuchi Formation, Gôroku Cliff, Sendai City. 5a — b, *Neogenella okadana* (Yokoyama), interior and exterior views of left valve, for comparison, U.H. Reg. No. 31011, $\times 1$, Tachikarashinai Formation, Utanobori-chou, northern Hokkaido.



morphological variation is observed in its related species *Neogenella okadana* (Yokoyama). Over 80 specimens of this species are measured and examined, the writer recognized that some old large specimens of *Neogenella okadana* tend to have more inflated or somewhat hump-back curvature along the postero-dorsal border, in general. This species from the type locality has large varietal form and ranges from typical hunch-back like *N. okadana* form to low convex even including *N. hokkaidoensis* form. The variation and its relation to geological and geographical distributions of this species will be discussed in another paper.

Geologic and paleozoogeographic distribution of *Gigantocallista*

The hunch-back like shells of the Miocene *Neogenella* species and Pliocene *Gigantocallista sendaica*, may be closely related to each other genetically and ecologically. Many distinctive morphological characters are shared by these species and they also show a remarkably crowded occurrence in coarse-grained sandstone. Based on associated fossils and substrate, they evidently lived on shallow, sandy, and level bottoms (Chinzei and Iwasaki, 1967). In Miocene time, *Neogenella* was distributed widely in eastern Asia, including Korea, Honshu, Hokkaido, Sakhalin, and western Kamchatka. During late Middle to Late Miocene time, *Neogenella* lived in Hokkaido, Sakhalin and western Kamchatka, but not to the south in Honshu and Korea. During this period, the Wakkanai and Atsunai-Togeshita Faunas occupied in those northern areas. It seems that

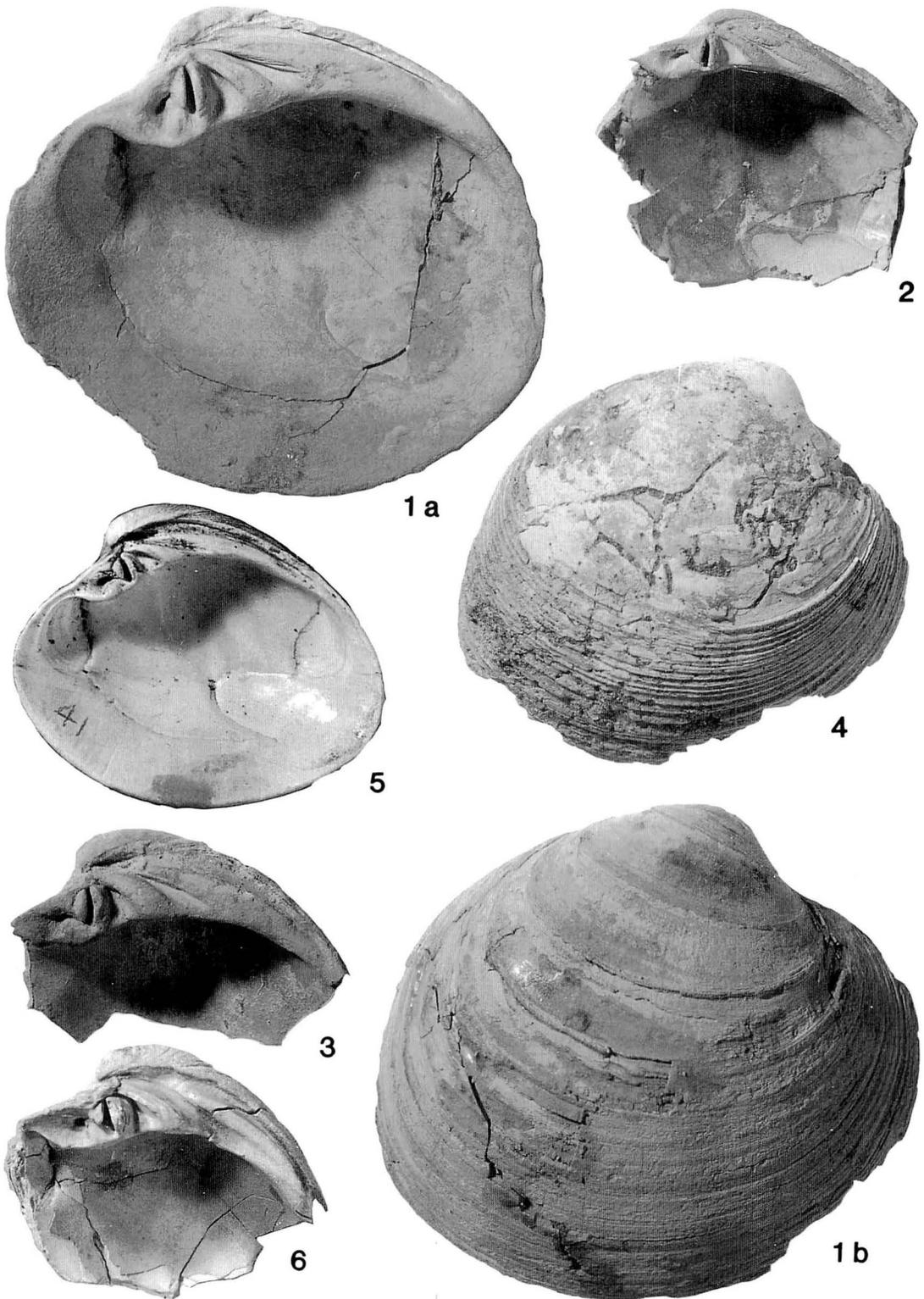
this faunas lived in water which was cool-temperate, but still slightly warm, because they were associated with intermingled cool and warm elements (Uozumi, 1962; Zhidkova *et al.*, 1968; Amano, 1983, 1986; Gladenkov, 1984; Menner, 1984).

Another hunch-back like venerid, *Gigantocallista*, was restricted geologically and geographically to the Pliocene Tatsunokuchi Fauna in the "Paleo-Sendai Bay" (Chinzei and Iwasaki, 1967; Masuda and Ogasawara, 1981). Though the Tatsunokuchi Fauna has been recognized to be composed of cool water elements, this fauna also includes some warm water elements such as *Trachycardium gorokuense*, *Meretrix parameritrix*, *Anisocorbula venusta*, and *Neverita kiritaniana* (Nomura, 1938). Since this fauna is composed of intermingled cool and warm elements, the Tatsunokuchi Fauna seems to have lived in water that was cool-temperate, but still somewhat warm.

In Pliocene time, the Takikawa-Honbetsu Fauna lived in Hokkaido, Sakhalin and Kamchatka, but not in the Miyagi Prefecture and its south. It seems that this fauna lived within cool-water currents, similar to those of the present day along the Pacific coast of eastern Hokkaido (Uozumi, 1962; Takagi, 1982; Uozumi *et al.*, 1986). In addition, *Dosinia tomikawensis* Takagi, one of the characteristic species of the Takikawa-Honbetsu Fauna, was distributed in Aomori, Hokkaido, and southern Sakhalin, but not in the Sendai Basin and further south (Takagi, 1986; Uozumi *et al.*, 1986).

The Tatsunokuchi and the Kakegawa Faunas were intermingled in the southern area of Sendai (=the Ishiguma Formation of

→ **Figures 7-1a — 4.** *Gigantocallista sendaica* (Nomura), **1a — b**, exterior and interior views of right valve, U.H. Reg. No. 31004, $\times 1$; **2 — 3**, hinge area of right valve, **2**: U.H. Reg. No. 31009, $\times 1.2$; **3**: U.H. Reg. No. 31010, $\times 1$; **4**, exterior view of the right valve, U.H. Reg. No. 31001, $\times 1$; **1a — 3**: Tatsunokuchi Formation, Chûdô 5 chôme, Sendai City; **4**: Tatsunokuchi Formation, Gôroku Cliff, Sendai City. **5**, *Pseudamiantis tauyensis* (Yokoyama), interior view of the right valve, for comparison, U.H. Reg. No. 31012, $\times 1$, Upper Ikeda Formation, Obihiro City, eastern Hokkaido. **6**, *Neogenella okadana* (Yokoyama), hinge area of right valve, for comparison, U.H. Reg. No. 31013, $\times 1$, Oiwake Formation (=upper Iwamizawa Formation), Iwamizawa City, central Hokkaido.



Futaba and Tomioka Formation of Hirono, Futaba-gun, Fukushima Prefecture). In these mixed fauna, *Fortipecten takahashii* (Yokoyama) or *F. kenyoshiensis* Chinzei, and cool-water elements, such as *Puncturella nobilis*, *Ariadnaria insignis*, *Turritella fortilirata*, *Velutina plicatilis cryptospira*, *Cryptonatica janthostoma*, *Nucella lamellosa*, *Nucella lapillus*, *Neptunea arthritica*, *Japelion pericochlion*, *Aulacofusus periscelidus*, *Obestoma simplex*, *Acirsa ochotensis*, *Glycymeris yesoensis*, *Limatula vladivostokensis*, and *Spisula polynyma* are associated with warm Kakegawa faunal elements (e.g., *Suchium giganteum yamamotoi*, *Neverita didyma*, *Adusta onyx*, *Sydaphera spengleriana*, *Turritella ikebei*, *Glycymeris* cf. *nakamurai*, *Chlamys miurensis*, *Chlamys satoi*, *Cryptopecten vesiculosus*, *Nemocardium samarangae*, and *Anisocorbula venusta*) (Hayasaka and Hangai, 1966; Masuda and Ogasawara, 1981; O'Hara and Nemoto, 1988; Noda, Kikuchi and Nikaido, 1989). Though it contains cool-water elements, this fauna of the Ishiguma and Tomioka Formations seemed to live in warm-temperate habitat, warmer than that of the Tatsunokuchi Fauna and the Takikawa-Honbetsu Fauna (Hayasaka and Hangai, 1966; Takahashi, 1986; Noda, Kikuchi and Nikaido, 1989).

Though this fauna includes *Fortipecten*, the molluscan fauna of the Ishiguma and Tomioka Formations is more similar to the southern Kakegawa Fauna than to the Tatsunokuchi and Takikawa-Honbetsu Faunas.

The Tatsunokuchi Fauna, which includes *Gigantocallista*, lived in distinctive conditions, which resemble those of the late Middle-Late Miocene of Hokkaido, Sakhalin and western Kamchatka. These distinctive conditions are reflected in the many endemic species of shallow, sandy, level-bottom dwellers that lived only within the Pliocene "Paleo-Sendai Bay". Such species include *Glycymeris gorokuensis* Nomura, *Chlamys sendaiensis* Masuda, *Ostrea palaeodensamellosa* Nomura, "*Erycina*" *sendaiensis*

Nomura, *Trachycardium gorokuense* Nomura, *Dosinia tatunokutiensis* Nomura, *Meretrix parameretrix* Nomura, "*Venerupus*" *hirosegawana* Nomura, *Tellina sendaica* Nomura, *Zirfaea hataii* Masuda and Noda, *Retusa gorokuensis* Nomura, *Batillaria shataii* Nomura, *Caecum yotume* Nomura, *Lacuna ihayasakai* Nomura, *Chlorostoma yabei* Nomura, *Sukenea basilirata* Nomura, and *Gigantocallista sendaica* (Nomura) (Nomura, 1938; Masuda, 1962; Hayasaka and Hangai, 1966; Masuda and Noda, 1969; Takagi, 1986; Masuda, 1986). These characteristic species in the Tatsunokuchi Fauna imply an unusual specialization under the influence of intermingled cold and warm currents caused by special zoogeographical conditions (Nomura and Hatai, 1936; Hayasaka and Hangai, 1966; Matsui, 1988; Noda, Kikuchi and Nikaido, 1989). As mentioned above, such a water condition was restricted geologically and geographically to the Pliocene, which is why *Gigantocallista* lived only within the Pliocene Paleo-Sendai Bay.

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venerid specimens from the Tatsunokuchi Formation in Sendai.

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Russian*)

Tatsunokuchi 竜ノ口, Sendai 仙台, Miyagi 宮城, Wakkanai 稚内, Atsunai-Togeshita 厚内
一峠下, Takikawa-Honbetsu 滝川-本別, Aomori 青森, Hokkaido 北海道, Ishiguma 石熊,
Futaba 双葉, Fukushima 福島, Kakegawa 掛川, Ikeda 池田, Obihiro 帯広, Utanobori 歌
登, Poroshin 幌新, Numata 沼田, Oiwake 追分, Iwamizawa 岩見沢.

Gigantocallista, 宮城県仙台市の鮮新世竜ノ口層 Veneridae 科 (二枚貝綱) の一新属: 本
邦の中新世および鮮新世より産する特異な形態をもついわゆる *Pitar* 属に含められてきた
貝化石の検討を行い, 宮城県仙台市の竜ノ口層から産する *Pitar sendaica* Nomura をもと
に新属 *Gigantocallista* を提唱する。本属は著しく大型でよく膨らんだ厚い殻, 重厚な鉸板,
独特の鉸歯等で特徴づけられる。*Gigantocallista* は, その形態的特徴 (特に鉸板, 鉸歯) が
中新世に広く産する *Neogenella* 属に良く類似し, 前者は後者から派生したことが強く示唆
される。また, 本属の分布は鮮新世のいわゆる古仙台湾に限られることや, 共産する貝類
化石も本属と同様の時代的, 地理的分布を示すものが著しく多いことから, *Gigantocallista*
は, 鮮新世の竜ノ口動物群の地理的・環境的な特異性を示すものと考えられる。高木俊男

904. EARLY CARBONIFEROUS (VISÉAN) CEPHALOPODS FROM THE HIKOROICHI FORMATION, SOUTHERN KITAKAMI MOUNTAINS*

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Abstract. A new Early Carboniferous cephalopod fauna is described from the Hikoroichi Formation of the southern Kitakami Mountains, northeast Japan. The fauna consists of five species including three new taxa: *Mooreoceras kinnoi*, sp. nov., *Neocycloceras* (?) sp., *Adnatoceras onimarensense*, sp. nov., *Dolorthoceras* (?) sp. and *Sueroceras nishimurai*, sp. nov. These are the first Carboniferous orthocerids from northeast Japan.

Key words. Hikoroichi Formation, Kitakami Mountains, Viséan orthocerid fauna.

Introduction

Carboniferous nautiloids from the Kitakami Mountains have been little investigated. To date only a single form, *Coelonautilus* sp. from the Lower Carboniferous of the Setamai area, Iwate Prefecture has been previously reported (Hayasaka, 1954). However, recent collections by the staff members of the Onimaru Quarry in the Hikoroichi area, Iwate Prefecture clarify the presence of a diverse molluscan fauna including cephalopods in the Lower Carboniferous Hikoroichi Formation at this quarry. Based mainly on this material, five species of orthocerid nautiloids including three new species are described herein.

Specimens utilized in this report are stored at Geological Section of Ofunato City Museum, Iwate Prefecture (OCM) or the University Museum of the University of Tokyo (UMUT).

Systematic paleontology

Order Orthocerida
Superfamily Pseudorthocerataceae
Flower and Caster, 1935
Family Pseudorthoceratidae
Flower and Caster, 1935
Subfamily Pseudorthoceratinae
Flower and Caster, 1935
Genus *Mooreoceras* Miller,
Dunbar and Condra, 1933

Type species. — *Mooreoceras normale* Miller, Dunbar and Condra, 1933, from the Middle Pennsylvanian of Kansas.

Mooreoceras kinnoi Niko, sp. nov.

Figures 1-1—3, 5

Material.— Holotype, OCM G-SN01, an imperfect phragmocone.

Diagnosis.— *Mooreoceras* with ornamentation of lattice pattern; siphuncle consists of barrel-shaped to pyriform connecting rings and cyrtochoanitic septal necks with very

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short brims.

Description.—The holotype is an orthoconic shell with a subcircular cross section, 70.5 mm in length. The shell surface is marked by fine cancellate ornamentation of longitudinal and transverse lirae. Sutures are oblique and faintly sinuous. Septa are relatively deep; approximately five camerae occupy the corresponding dorsoventral shell diameter. The siphuncle is situated centrally and composed of barrel-shaped to pyriform connecting rings and cyrtochoanitic septal necks; dorsal necks are abruptly recurved (Figure 1-5). Siphuncular segment heights range from 2.5 to 3.3 mm; maximum segment expansion is 3.0 mm in width. Width [max.]/height ratio of siphuncular segments ranges from 0.93 to 1.10. Brims are very short. Camerae and endosiphuncle lack evident biogenic deposits.

Remarks.—The sinuate and oblique sutures, broadly inflated connecting rings, and absence of both cameral and siphonal deposits suggest that the new species belongs to the genus *Mooreoceras* Miller, Dunbar and Condra, 1933. Other species of *Mooreoceras*, however, lack conspicuous surface ornamentation, whereas *M. kinnoi* has cancellate markings of lirae.

Occurrence and age.—This species was recovered from a calcareous sandstone bed of the H₂ Member (Kawamura, 1983), Hikoroichi Formation at the Onimaru Quarry (loc. NSM-PCL6-53-3, see fig. 1 in Kase, 1988). The calcareous sandstone bed has been regarded as Viséan in age, based on the productid brachiopods (Tazawa, 1984) and gastropods (Kase, 1988).

Etymology.—The species is named in honor of S. Kinno, who discovered this cephalopod.

Genus *Neocycloceras*
Flower and Caster, 1935

Type species.—*Neocycloceras obliquum*
Flower and Caster, 1935 from the Upper

Devonian of Pennsylvania.

Neocycloceras (?) sp.

Figure 1-4

Material.—One figured specimen, UMUT PM 18784.

Remarks.—A single deformed and fragmentary shell, 28.4 mm in length, is tentatively referred to the genus *Neocycloceras* Flower and Caster, 1935 based on its slender shell shape, and slightly oblique and scattered annulations. The shell surface is also sculptured by transverse lirae; each interspace of annulation is marked by five to six transverse lirae. The internal structure is not preserved.

The surface ornamentation of the present species is most similar to *Neocycloceras harrisi* Flower and Caster, 1935 from the Upper Devonian of Pennsylvania. However, *N. harrisi* differs from this species in having a closer spacing of annulations and lirae. The present species can be distinguished from *Cycloceras dombarensis* Shimansky, 1968 from the Lower Namurian of southern Urals, U.S.S.R., in that the latter possesses a less slender shell.

Occurrence and age.—Same as *Mooreoceras kinnoi* Niko, sp. nov.

Subfamily Spyroceratinae
Shimizu and Obata, 1935
Genus *Adnatoceras* Flower, 1939

Type species.—*Orthoceras spissium* Hall, 1879 from the Middle Devonian of New York.

Adnatoceras onimarensis Niko, sp. nov.

Figures 2-5

Material.—Holotype, UMUT PM 18785, an imperfect phragmocone.

Diagnosis.—*Adnatoceras* characterized by slowly expanding shell of elliptical cross section and subcentral siphuncular position.



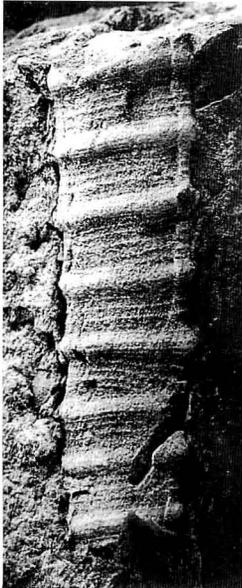
1



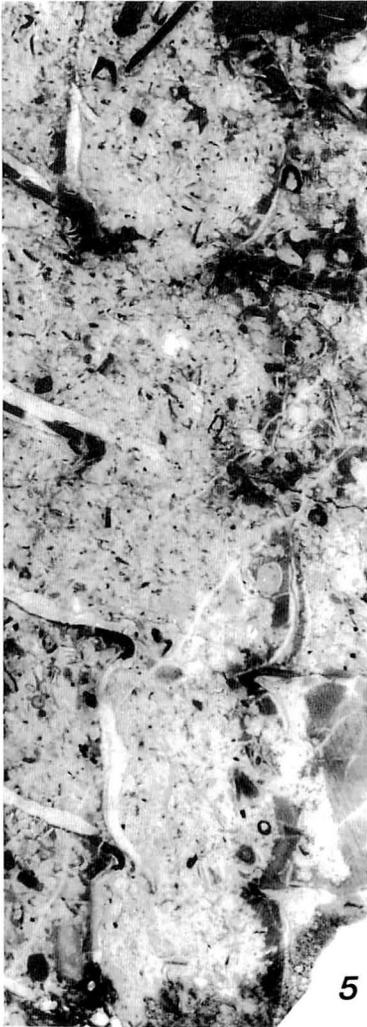
2



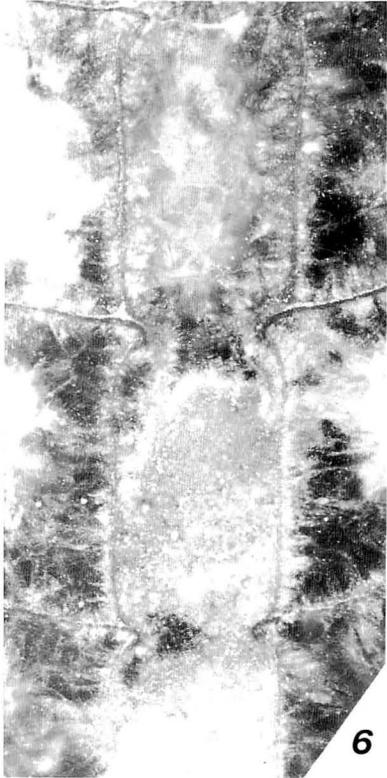
3



4



5



6

Cameral deposits episeptal-mural and hyposeptal type which form pseudoseptum in ventral side. Endosiphuncular deposits form continuous lining on ventral wall.

Description.—The holotype is a slowly expanding phragmocone, 47.0 mm in length, with an elliptical cross section and smooth shell surface. Diameter of the conch is 6.0×4.5 mm at the apical end and expands up to approximately 7.5 mm (dorsoventral diameter) over the length of the fragment. Septa are moderately curved; approximately two and one-half to three camerae occupy the corresponding dorsoventral shell diameter. The siphuncle occupies a subcentral position, and consists of cylindrical connecting rings and subcyrtocoanitic septal necks; connecting rings are abruptly contracted at the septal foramen (Figure 2-4). Siphuncular segment heights range from 1.4 to 2.4 mm; maximum segment expansion is 1.1 mm in width. Width[*max.*]/height ratio of siphuncular segments ranges from 0.54 to 0.67. The area of adnation is nearly equal to the width of brims. Cameral deposits are well developed. On the ventral side of the siphuncle, deposits can be differentiated into episeptal-mural and hyposeptal deposits, and they form pseudoseptum. Dorsally, biogenic carbonates consist of episeptal-mural deposits. Endosiphuncular annulus deposits are restricted to the ventral side, and fusing to form continuous lining.

Remarks.—*Adnatoceras onimarensis*, sp. nov., most resembles *A. ichinotaniense* Niko and Hamada, 1987 from the upper Bashkirian of the Ichinotani Formation, central Japan, in that both taxa possess a slender shell with smooth surface and hyposeptal deposits. The former species, however, does not exhibit a rapid siphuncular shifting to the venter as the shell growth, unlike *A. ichinotaniense*.

Furthermore, the latter species has a less elliptical cross section than that of the former. *A. araskense* Gordon, 1957 from the middle to upper Viséan of Alaska, is also similar to the present species in the siphuncular structure, but differs in having a circular cross section of the shell and more rapid shell expansion. In addition, *A. araskense* lacks hyposeptal deposits. *A. kipchakense* Shimansky, 1968 from the lower Viséan of Kazakhstan, U.S.S.R. is easily distinguished from *A. onimarensis* by its larger shell expansion ratio.

Occurrence and age.—Same as *Mooreoceras kinnoi* Niko, sp. nov.

Etymology.—The species is named for the occurrence at Onimaru Quarry.

Genus *Dolorthoceras* Miller, 1931

Type species.—*Dolorthoceras circulare* Miller, 1931, from the Upper Carboniferous of the Karakoram Mountains, India.

Dolorthoceras (?) sp.

Figure 2-1

Material.—Figured specimen, UMUT PM 18787, an imperfect phragmocone.

Remarks.—A single orthoconic phragmocone of moderately expanding shell represented by a cast and silicified connecting ring. The specimen is 37.0 mm in length and increases in diameter from 4.5 to 8.7 mm over the fragment. There is no obvious external ornament. Septa are gently to moderately curved, forming straight and slightly oblique sutures. The siphuncle shifts slightly ventral side in the adoral part; its segment is expanded in camerae. Cameral deposits consist of L-shaped episeptal-mural type.

← **Figure 1.** 1-3, 5, *Mooreoceras kinnoi* Niko, sp. nov., holotype, OCM G-SN01, 1, ventral view, $\times 1.5$; 2, silicon rubber cast, showing surface ornamentation, $\times 5.0$; 3, dorsoventral thin section, venter left, $\times 3.0$; 5, partial enlargement of Figure 1-3, showing siphuncular structure, $\times 8.0$. 4, *Neocycloceras* (?) sp., UMUT PM 18784, lateral view, $\times 2.5$. 6, *Sueroceras nishimurai* Niko, sp. nov., partial enlargement of Figure 3-5, showing siphuncular structure, $\times 8.0$.

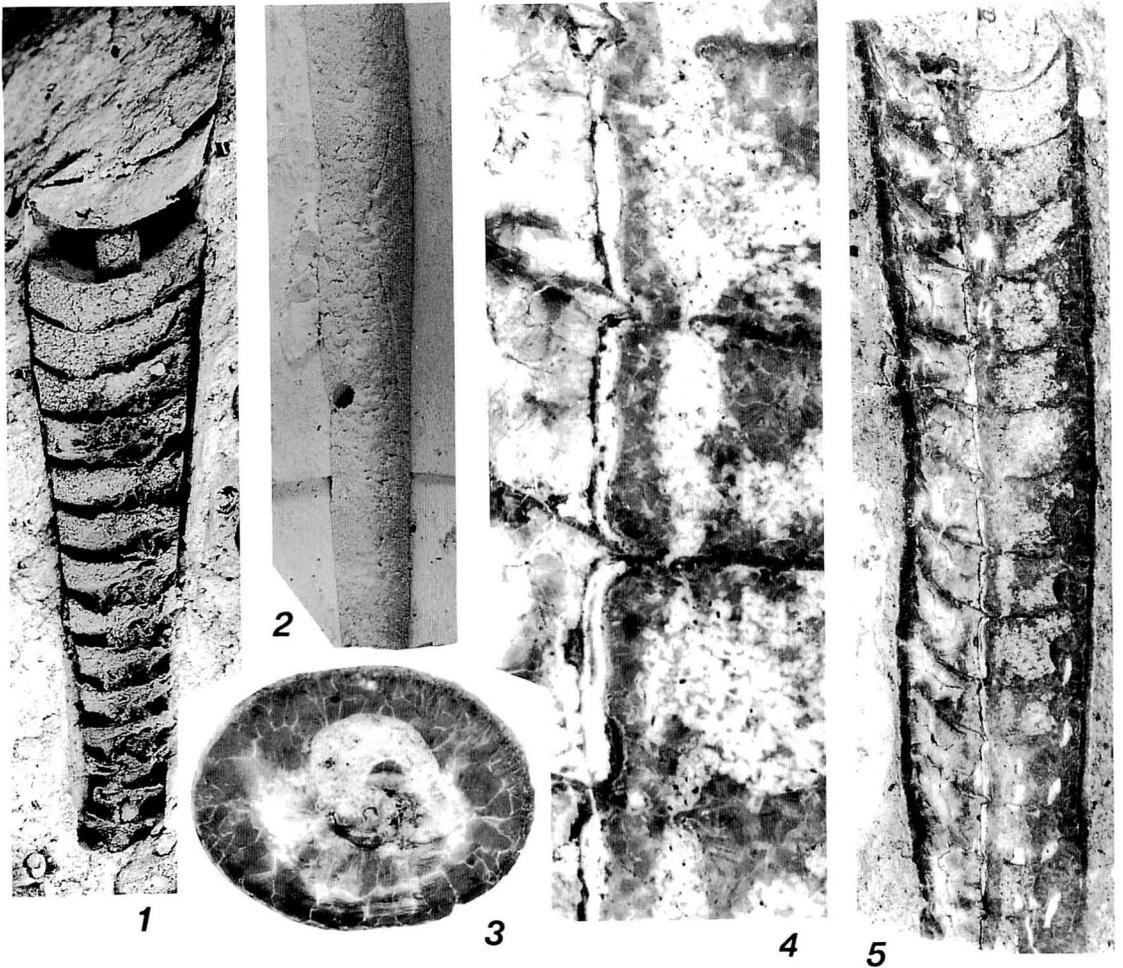


Figure 2. 1, *Dolorthoceras* (?) sp., UMUT PM 18787, weathered lateral view venter right, $\times 3.0$. 2—5, *Adnatoceras onimarensis* Niko, sp. nov., holotype, UMUT PM 18785; 2, lateral view of silicone rubber cast, venter left, $\times 2.0$; 3, cross thin section near apical end of the specimen, venter down, $\times 8.0$; 4, partial enlargement of Figure 2-5, showing siphuncular structure, $\times 15.0$; 5, dorsoventral thin section, venter left, $\times 4.0$.

These features are characteristic of typical pseudorthoceratids such as *Dolorthoceras* Miller, 1931 but poor preservation of the internal structure makes taxonomic assignment of the specimen equivocal.

Occurrence and age.—Same as *Mooreoceras kinnoi* Niko, sp. nov.

Genus *Sueroceras* Riccardi
and Sabattini, 1975

Type species.—*Sueroceras irregulare* Riccardi and Sabattini, 1975, from the Carboniferous of Chubut, Argentina.

Sueroceras nishimurai Niko, sp. nov.

Figures 1-6, 3-1-6

Material.—Holotype, OCM G234, an imperfect phragmocone. Paratypes, OCM G235, a small fragment of external shell;

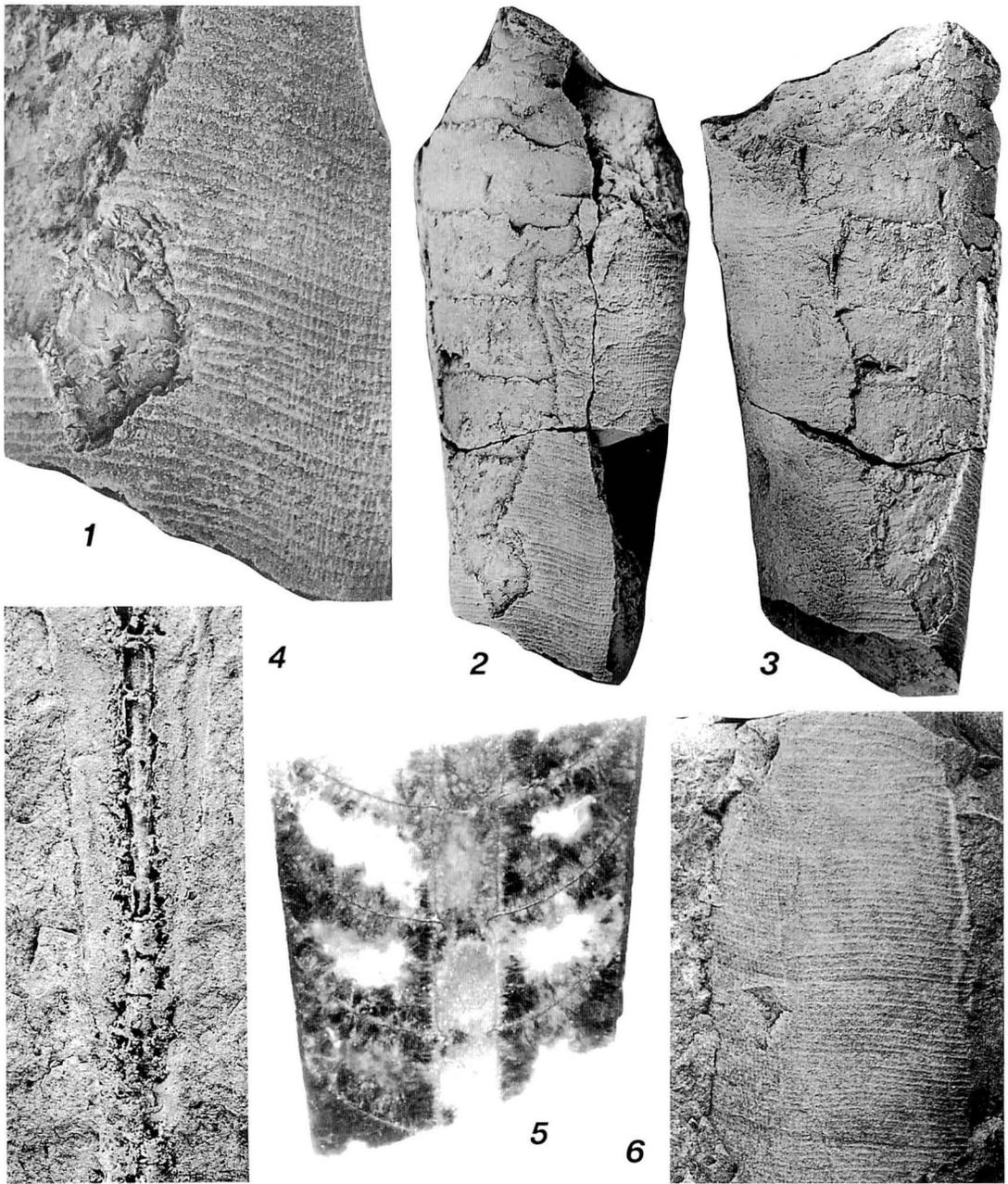


Figure 3. *Sueroceeras nishimurai* Niko, sp. nov., 1 — 3, 5, holotype, OCM G234, 1, partial enlargement of Figure 3-2, showing surface ornamentation, $\times 5.0$; 2, dorsal view, $\times 2.0$; 3, lateral view, venter left, $\times 2.0$; 5, dorsoventral polished section, venter right, $\times 3.0$. 4, paratype, OCM G236, weathered shell, apical end of the specimen, $\times 3.0$. 6, paratype, OCM G235, lateral view, venter right, $\times 2.0$.

OCM G236, a deformed phragmocone with partial body chamber.

Diagnosis.—*Sueroceras* with relatively rapid shell expansion, subcircular cross section, sinuous transverse lirae, and fine longitudinal lirae which disappear on ventral side in advanced growth stages. Siphuncular position subcentral; septal necks very short and partly cyrtochoanitic. Connecting rings strongly contracted at septal foramen.

Description.—The holotype is an orthoconic phragmocone, 62.1 mm in length, with subcircular cross section. The shell diameter of the apical end is 15.7×14.2 mm. The surface ornamentation exhibits reticulate pattern; it is composed of considerably sinuous transverse lirae, and fine longitudinal lirae of which spacing shifts dorsalward to close. Sutures are straight and slightly oblique. Septa are moderately curved; approximately three camerae occupy the length of apical conch diameter. The siphuncle is subcentral and circular in cross section; it consists of suborthochoanitic to cyrtochoanitic septal necks, and cylindrical connecting rings which are strongly and abruptly constricted at the septal foramen (Figure 1-6). Siphuncular segment heights range from 5.2 to 5.5 mm; maximum segment expansion is 3.5 mm in width. Width[*max.*]/height ratio of siphuncular segments is approximately 0.59. Brims are very short. Biogenic carbonates are not preserved in the present material.

One of the paratypes (OCM G235, Figure 3-6) is a fragment of the shell wall, approximately 40 mm in length. The shell surface is sculptured by sinuous and closely spaced transverse lirae that are replaced by coarse transverse lirae with broad salients in adoral shell, and dorsal ornamentation of longitudinal lirae.

The other paratype (OCM G236, Figure 3-4) is a natural mold of flattened orthoconic shell, approximately 110 mm in length, and this represents earlier growth stages than the holotype and the other paratype. Approximately one-half of the shell is a body chamber

that bears transverse and fine longitudinal lirae. Connecting rings are cylindrical and constricted at the septal foramen.

Remarks.—The present species is placed in the genus *Sueroceras* Riccardi and Sabattini, 1975, because of the characteristic reticulate surface markings with *Dolorthoceras*-like internal structure.

Eight species from the Lower Carboniferous to Permian had been referred or tentatively assigned to *Sueroceras*. Among them this species is most similar to *S. irregulare* Riccardi and Sabattini, 1975 in general morphology of the siphuncle. It differs from *S. irregulare* by having a more rapidly expanding conch, cyrtochoanitic septal necks with abruptly contracted connecting rings, and closer septal spacing. Moreover, longitudinal lirae of the present new species are coarser than in *S. irregulare*.

Occurrence and age.—Same as *Mooreoceras kinnoi* Niko, sp. nov.

Etymology.—The species is named in honor of S. Nishimura, who discovered this cephalopod.

Acknowledgments

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Hikoroichi 日頃市, Ichinotani 一の谷, Kitakami Mountains 北上山地, Ofunato 大船渡,
Oimaru 鬼丸, Setamai 世田米.

南部北上山地日頃市層産石炭紀前期(ビゼー世)頭足類:南部北上山地の岩手県大船渡市鬼丸採石場に露出する下部石炭系日頃市層のH₂部層(ビゼー世)から頭足類を含む多様な軟体動物化石群を産出することが、同採石場の西村智、金野敏両氏らの採集標本により明らかになった。本論では、3新種を含むオルソセララス目の頭足類5種を記載した。それらは、*Mooreoceras kinnoi*, sp. nov., *Neocycloceras* (?) sp., *Adnatoceras onimarensense*, sp. nov., *Dolorthoceras* (?) sp., *Sueroceras nishimurai*, sp. nov. で、東北日本からの石炭紀オルソセララス目頭足類産出の初記録となる。
兒子修司

905. LOWER JURASSIC RADIOLARIAN ZONES OF SW JAPAN*

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Abstract. Four Lower Jurassic radiolarian assemblage-zones and four subzones are established on the basis of radiolarian biostratigraphic data from the Inuyama and three other areas of SW Japan. These zones are as follows in ascending order: the *Parahsuum simplum* (divided into Subzone I to IV), *Mesosaturnalis hexagonus* (newly proposed), *Parahsuum* (?) *grande* and *Hsuum hisuikyoense* Assemblage-zones. These zones range in age from latest Triassic/earliest Jurassic (Rhaetian/Hettangian ?) to early Middle Jurassic (Bajocian). This age assignment is based on comparison with Early to Middle Jurassic radiolarian biostratigraphy established in North America and Turkey.

Key words. Lower Jurassic, radiolarian assemblage-zones, SW Japan.

Introduction

Studies of Jurassic radiolarian biostratigraphy have advanced rapidly during the past two decades. In Japan, a pioneer study on Jurassic radiolarian zonation was made by Yao *et al.* (1980) in the Inuyama area of central Japan. At that time, each radiolarian zone represented an average of 10 m.y. interval. Needs for radiolarian zones spanning shorter time ranges than those hitherto established has increasingly been felt for undertaking more precise analysis of stratigraphic sequences. Since then, many workers have proposed various zones which were summarized by Yao (1986). These zonations, however, produced some confusion.

The purpose of this paper is to revise and rearrange the radiolarian zones that had been established for the Lower Jurassic of Japan and to discuss their ages through a comparison with radiolarian data from North America and Turkey. Each radiolarian zone de-

scribed in this paper represents approximately half a 10 m.y. time span and the zonal framework is derived from the assemblage-zones proposed by Yao (1982) and Yao *et al.* (1982).

Geologic setting

The Lower Jurassic radiolarian zones described in this paper are based upon biostratigraphic data obtained from continuous sequences of Upper Triassic to Middle Jurassic strata in SW Japan. These sequences all share almost the same lithostratigraphy, in which the lower part is composed of bedded chert and the upper part of clastic rocks. These units generally occur in a pile of imbricate tectonic slices and/or blocks in the Mesozoic subduction-accretion complexes.

Eleven measured sections have been chosen for the present biostratigraphical study. These sections are located in four distinct areas in SW Japan: six in the Inuyama area and one in the Mt. Norikuradake area of the Mino Belt, two in the Kuzuu area of the

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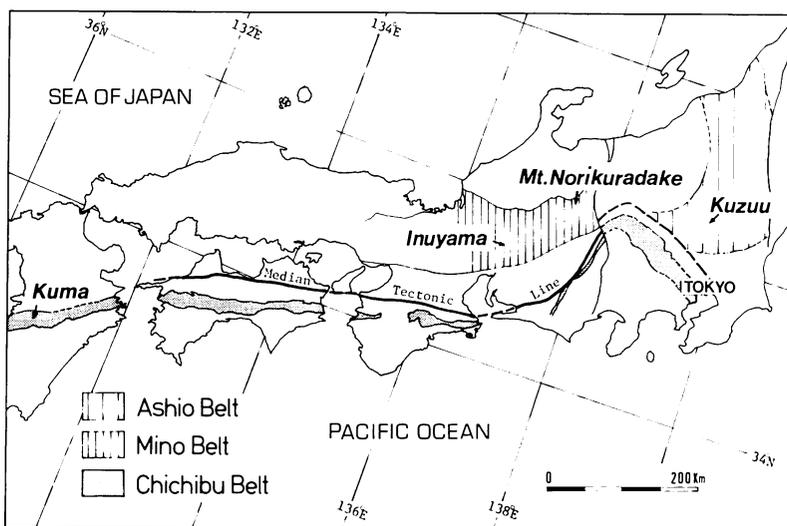


Figure 1. Localities of the Kuma, Inuyama, Mt. Norikuradake and Kuzuu areas of Japan.

Ashio Belt, and two in the Kuma area of the Chichibu Belt in Kyushu (Figure 1).

A. Inuyama area (lat. $35^{\circ}25 \pm 2'N$, long. $136^{\circ}58 \pm 2'E$)

The sedimentary complex exposed in this area comprises bedded cherts and clastic sedimentary rocks forming a large synform called the "Sakahogi Syncline" (Mizutani, 1964), and its lithologic distribution was studied in detail by Kondo and Adachi (1975), however, both stratigraphic and tectonic interpretations of the Triassic conodont occurrences in cherts underlie or overlie clastic rocks, which yield ammonite and plant fossils of Jurassic age had not been fixed. Yao *et al.* (1980) carefully examined the distribution of radiolarians and conodonts in chert and clastic sedimentary rocks and found that imbricate slices composed of Triassic to Lower Jurassic chert and Middle Jurassic (and possibly much younger) clastic sedimentary rocks, were tectonically repeated at least four times (Figure 2).

A generalized columnar section of the chert and clastic sedimentary rocks in this area is shown in Figure 3. The section consists of the following six lithologic units in ascending

order; 1) pale-green and black claystone with pyrite nodules, thin chert layer and dolomite; 2) varicolored bedded chert; 3) red and green siliceous mudstone; 4) black mudstone with thin sandstone layer; 5) massive sandstone; 6) sandstone with mudstone layer and tuff. The age of these rocks ranges from Middle Triassic or Early Triassic? (Mizutani and Koike, 1982) to Middle or Late Jurassic (Adachi, 1988). Six chert sections were measured and sampled for this radiolarian study and their locations are shown in Figure 2.

Katsuyama (UF) Section: This is one of the most complete sections of Upper Triassic to Lower Jurassic strata (ca. 32 m thick) available in this area. Nakaseko and Nishimura (1979) described Late Triassic radiolarians from a chert in the lower part of this section. Fragments of Mesozoic plant fossils were obtained from sandstone overlying the chert (Nishida *et al.*, 1974). A late Bathonian-early Callovian ammonite, *Choffatia* (*Subgrossouvia*) sp. was reported from a black siltstone float near this section (Sato, 1974; Sato and Westermann, 1985). This ammonite was probably derived from a mudstone facies of the clastic slice resting

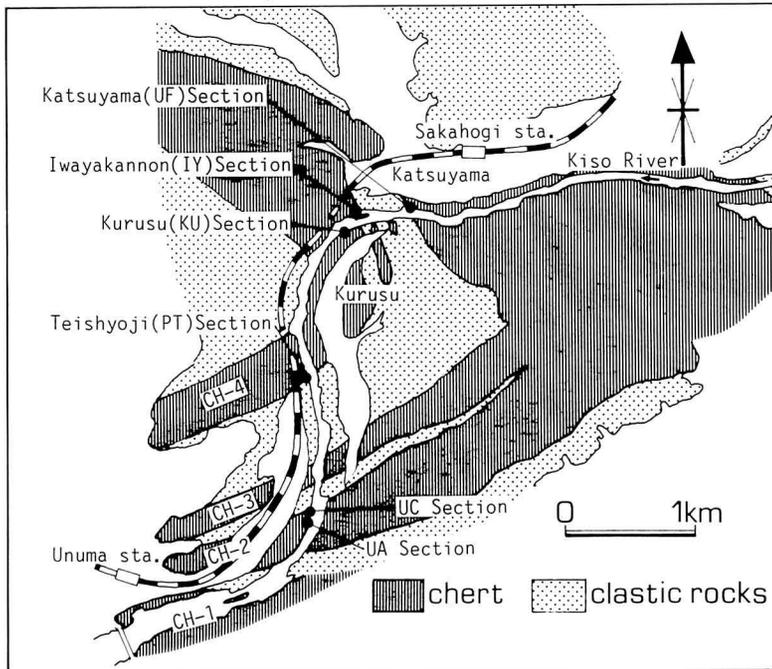


Figure 2. Geological sketch map of the Inuyama area (modified from Kondo and Adachi, 1975; Yao *et al.*, 1980) and locations of measured sections.

upon the chert unit (CH-3?).

Iwayakannon (IY) Section: This section is located at the chert unit, CH-4 of Yao *et al.* (1980), and consists of an approximately 25 m of bedded chert that is Early Jurassic in age (Hori, 1988). The chert is coherent with a Middle Jurassic mudstone at the top, though there is a stratigraphic break between the two. This break is equivalent to the *Hsuum hisui-kyoense* Assemblage-zone of Yao and Matsuoka (1981).

Kurusu (KU) Section: This section represents a complete sequence of Upper Triassic to Lower Jurassic strata including the Triassic-Jurassic boundary. It is composed of a 35 m thick sequence of rhythmically interbedded chert and mudstone (Hori, 1988).

Teishyoji (PT) Section: This section is located above the chert unit CH-4 and structurally equivalent to the IY Section mentioned above. At the top of this section, the chert which represents the *Parahsuum* (?)

grande Assemblage (Yao *et al.*, 1982) is coherent with sandstone (Matsuda *et al.*, 1981).

UC Section: The section is composed of a rhythmically interbedded sequence of chert and mudstone (Hori, 1986). The upper part of this section corresponds to the section studied by Isozaki and Matsuda (1985a).

UA Section: This section corresponds to the uppermost part of the section studied by Yao *et al.* (1980) and Yao (1982). Hori (1986) documented stratigraphic distribution of selected radiolarian species. The chert of this section includes the stratotype of the *Parahsuum simplex* Assemblage (Yao, 1982).

B. Mt. Norikuradake area (lat. $36^{\circ}, 8 \pm 1'N$, long. $137^{\circ}, 37 \pm 1'E$)

The Mesozoic sedimentary complex of this area is called Yukawa Complex and can be correlated with that of the Inuyama area

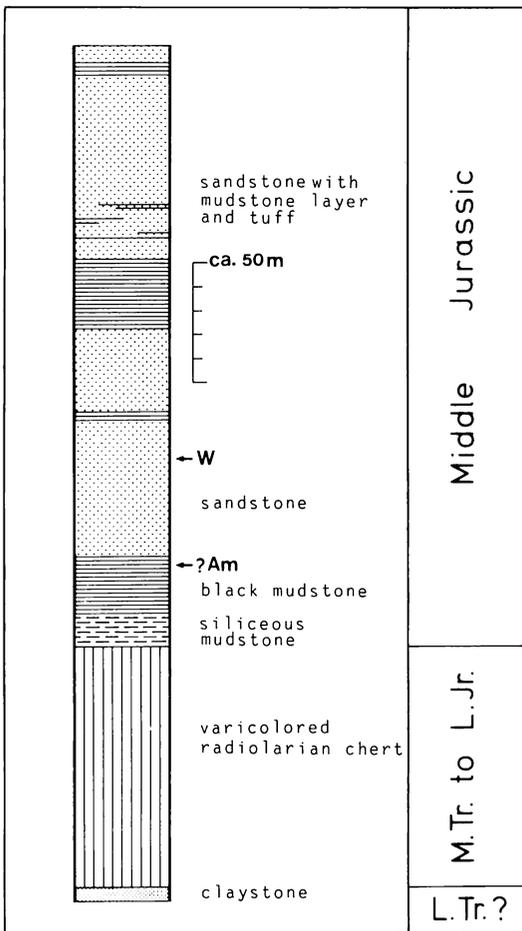


Figure 3. Generalized columnar section of the Inuyama area. Lithologic units and ages are based on conodont and radiolarian data. W: stratigraphic position of fossil fragments of petrified Mesozoic wood. ?Am: possible stratigraphic position of a late Bathonian-early Callovian ammonite.

based on similarities in the lithologic succession (Otsuka, 1988). The NK Section located 1 km northwest of Kanayama in the Norikura highlands consists of bedded chert and siliceous mudstone. Horii and Otsuka (1989) reported the stratigraphic distribution of well-preserved radiolarians from this section.

C. Kuzuu area (lat. 36° , $26 \pm 4'N$, long. 139° , $35 \pm 4'E$)

Igo and Nishimura (1984) reported Upper

Triassic to Lower Jurassic radiolarians from a continuous chert sequence of the "Aoyama Formation" in this area. They recognized four radiolarian assemblage-zones for the Upper Triassic to Lower Jurassic interval. Two sections, KuA (KA) and KuB-C-D (KD) were examined in this study. The KA Section corresponds to the upper part of the Section C of Igo and Nishimura (1984) and consists of a dark gray bedded chert of about 8 m in thickness. The other section, KuB-C-D (KD) is the upper part of the Section B reported by Igo and Nishimura (1984). It consists of a rhythmically interbedded sequence of chert and mudstone approximately 35 m in thickness, which is overlain by sandstone. Immediately below the chert-sandstone contact, *Brachyoxylon* (silicified wood) was found (Iijima *et al.*, 1988). Radiolarians obtained from this section are Early to Middle Jurassic in age.

D. Kuma area (lat. 32° , $21 \pm 4'N$, long. 130° , $37 \pm 4'E$)

Late Paleozoic and Mesozoic radiolarians from this area were studied by Nishizono *et al.* (1982), Nishizono and Murata (1983), Sato and Nishizono (1983), Sato *et al.* (1986) and others. Sato *et al.* (1986) established 13 radiolarian zones for the Lower Triassic to Upper Jurassic interval in this area. Two sections, the Kaiji (KG) and Kajiki (KS) Sections were investigated in this study.

The lithology and correlation of all measured sections are shown in Figure 4. The distribution of representative radiolarian species in these sections studied are shown in Table 1.

Radiolarian zonation

Four radiolarian assemblage-zones in the Upper Triassic to lower Middle Jurassic of the studied areas are described in this paragraph. These zones are the *Parahsuum simplex* (Ps), *Mesosaturnalis hexagonus* (Mh), *Parahsuum (?) grande* (Pg), *Hsuum hisui-*

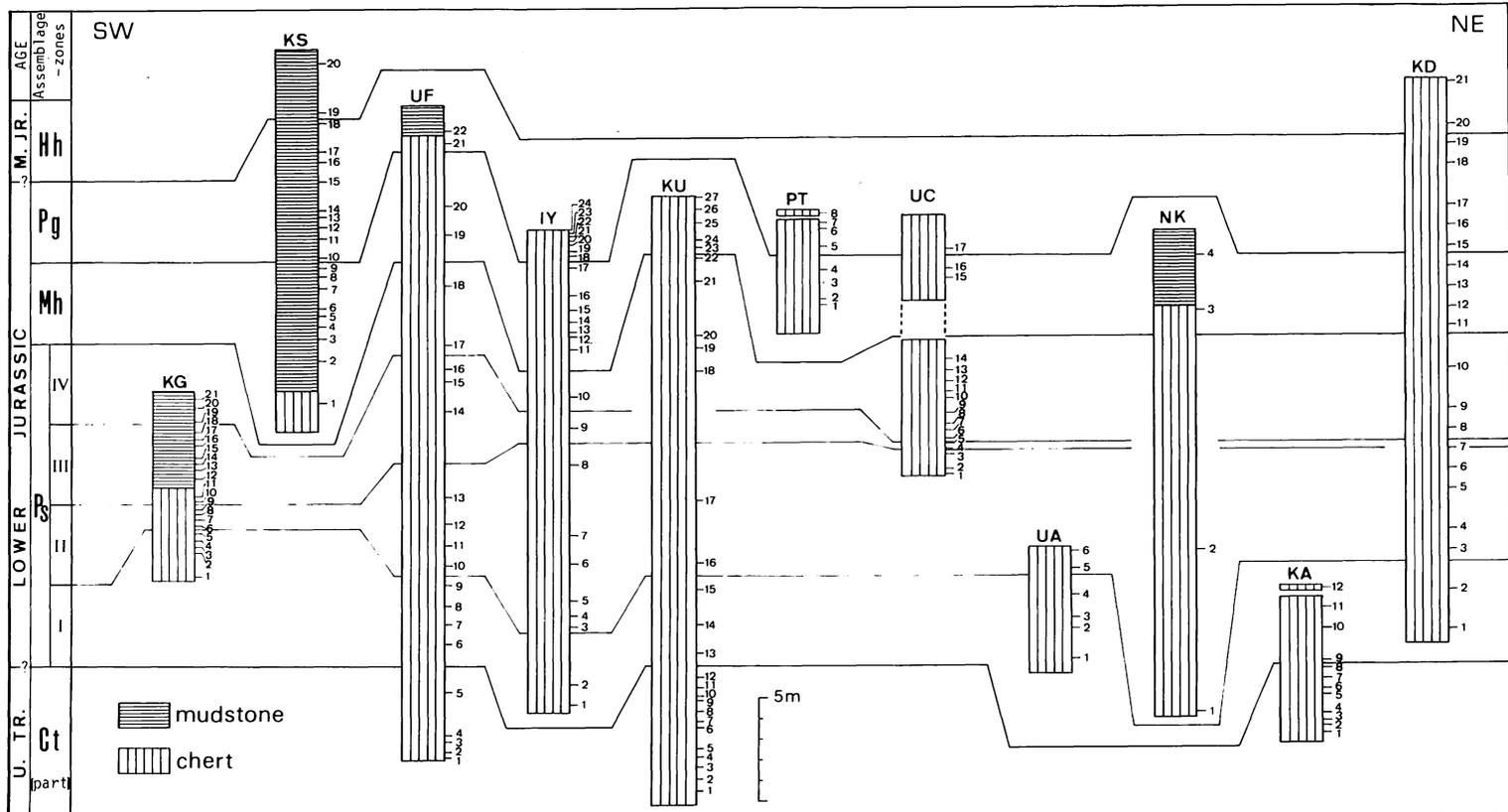


Figure 4. Lithology and correlation of the sections studied (see text for section names), showing selected sample localities, which yielded those radiolarian species listed in Table 1. Hh: *Hsuum hisuikyoense* Assemblage-zone; Pg: *Parahsuum* (?) *grande* Assemblage-zone; Mh: *Mesosaturnalix hexagonus* Assemblage-zone; Ps: *Parahsuum simplex* Assemblage-zone; Ct: *Canoptum triassicum* Assemblage-zone. All the assemblage-zones are described in the text with the exception of the Ct Assemblage-zone proposed by Yao (1982).

kyoense (Hh) Assemblage-zones in ascending order. Furthermore, four subzones of the Ps Assemblage-zone are proposed on account of species composition. The Mh Assemblage-zone is newly proposed herein.

A. Definition of zone

Radiolarian zones are defined by the presence of a characteristic species or a pair of such species and in practice, taking maximum ranges of characteristic species into consideration. This concept is similar to the radiolarian zonation based on the Unitary Associations method (e.g., Baumgartner *et al.*, 1980; Baumgartner, 1984). Because which species among the Lower Jurassic radiolarians is endemic or pandemic is not known, there is a problem of selecting a species pair suitable for establishing a zonation by the use of U.A. method. Thus, further work is required to apply the U.A. method to a Lower Jurassic radiolarian zonation.

The upper boundary of four zones is defined as the level which corresponds to the lower boundary of the superjacent or overlying zone. These four zones are described below beginning with the lowest.

1. *Parahsuum simplum* (Ps) Assemblage-zone (Yao, 1984, emended)

The base of this zone is defined by the lowest occurrence of *P. simplum* in association with *Dictyomitrella* sp. C.

The present author selected the UF Section (UF6-16) of the Inuyama area as the stratotype of this assemblage-zone and the following species including two diagnostic species, *Parahsuum simplum* Yao, *P. ovale* Hori and Yao, are characteristic in this zone. These species are: *Ares* (?) sp. D (= *Parares* sp. of Takemura, 1986), *Bipedis* sp. A, *B.* sp. B, *Dictyomitrella* sp. C of Yao (1982), *Dumitricaella* (?) sp. A, *Eucyrtidiellum* (?) sp. C group of Nagai (1986), *Gigi* aff. *fustis* De Wever, *Gorgansium gongyloideum* Kishida and Hisada, *G.* aff. *gongyloideum*, *Katroma kurusuensis* Hori, *K.* cf. *bicornus* De Wever, *Pantanellium* cf. *kluense* Pessagno and

Blome, *P.* aff. *kluense*, *P.* cf. *danaense* Pessagno and Blome, *Parahsuum* aff. *longiconicum* Sashida, *Syringocapsa coliforme* Hori, *S.* sp. B of Yao (1982), *Trillus elkhornensis* Pessagno and Blome, *Xenorum* sp. A, *Bagotum* spp., *Napora* spp., and *Zartus* spp.

The geologic range of this zone is the uppermost Triassic to middle Lower Jurassic (upper Pliensbachian to Toarcian?).

Remarks: The *Dictyomitrella* sp. C-*Archaeodictyomitra* sp. A Assemblage was first proposed from the Inuyama area by Yao *et al.* (1980). Subsequently, Yao (1982) renamed it as the *Parahsuum simplum* (Ps) Assemblage. A biostratigraphic unit assignable to the Ps Assemblage was first described by Yao (1984) from the Kii-Yura area of the Chichibu Belt.

This assemblage-zone is subdivided into four (I-IV) subzones in ascending order such as: the *Parahsuum* aff. *longiconicum*, *Katroma kurusuensis*, *Eucyrtidiellum* (?) sp. C, and *Trillus elkhornensis* Subzones.

Subzone I (*Parahsuum* aff. *longiconicum* Assemblage-zone)—The following species are obtained from this subzone: *Bipedis* sp. A, *B.* sp. B, *Dictyomitrella* sp. C of Yao (1982), *Gigi* spp., *Gorgansium gongyloideum*, *G.* aff. *gongyloideum*, *Pantanellium* aff. *kluense*, *P.* cf. *kluense*, *Parahsuum ovale*, *P. simplum*, *P.* aff. *longiconicum*, *Syringocapsa coliforme*, *S.* sp. B of Yao (1982), and *Xenorum* sp. A. Among them, *Gorgansium gongyloideum*, *G.* aff. *gongyloideum*, *Xenorum* sp. A and *Pantanellium* aff. *kluense* are dominated species. The range of these species extends downwards into the *Canoptum triassicum* (Ct) Assemblage-zone (Yao, 1984).

The geologic range of this subzone is the uppermost Triassic (Rhaetian) to lowest Jurassic (Hettangian to Sinemurian?).

Subzone II (*Katroma kurusuensis* Assemblage-zone)—This zone yields *Ares* (?) sp. D (= *Parares* sp. of Takemura, 1986), *Bagotum* spp., *Bipedis* sp. A, *B.* sp. B, *Dictyomitrella* sp. C of Yao (1982), *Dumitricaella* (?) sp. A, *Gigi* aff. *fustis*, *Katroma kurusuensis*, *K.* cf. *bicor-*

nus, *K. sp. N* of Hori (1988), *Pantanellium* cf. *danaense*, *Parahsuum ovale*, *P. simplum*, *Syringocapsa coliforme*, *S. sp. B* of Yao (1982), *Xenorum sp. A*, and *Zartus (?) sp.* This subzone is defined by the co-occurrence of *K. kurusuensis* and *G. aff. fustis*. Many specimens of taxons belonging to the genus *Katroma* (e.g., *K. kurusuensis*, *K. bicornus* and *K. sp. N*) are found in this zone. Rare specimens belonging to the species of the genus *Bagotum* are observed in the chert sequences, but this genus is also common, and occasionally abundant, in a mudstone facies, e.g., Kaiji Section of Kyushu.

The range of this subzone is the Lower Jurassic (Sinemurian to lower Pliensbachian?).

Subzone III (*Eucyrtidiellum (?) sp. C* Assemblage-zone) — This zone is characterized by the following species: *Ares (?) sp. D* (= *Parares sp. of Takemura, 1986*), *Bagotum* spp. (e.g., *B. modestum* Pessagno and Whalen), *Eucyrtidiellum (?) sp. C* group of Nagai (1986), *Katroma kurusuensis*, *Napora* spp., *Parahsuum ovale*, *P. simplum* Yao, *Dumitricaella (?) sp. A*, and *Zartus* spp. The base of this zone is defined by the lowest occurrence of *Eucyrtidiellum (?) sp. C* group. Near the base of this zone, the following species make their apparent final occurrences; *Bipedis sp. A*, *B. sp. B*, and *Gigi aff. fustis*.

The geologic range of this zone is the Lower Jurassic (lower Pliensbachian? to upper Pliensbachian).

Subzone IV (*Trillus elkhornensis* Assemblage-zone) — This subzone yields the following species: *Bagotum* spp., *Dumitricaella (?) sp. A*, *Eucyrtidiellum (?) sp. C* group of Nagai (1986), *Katroma kurusuensis*, *Napora* spp., *Parahsuum ovale*, *P. simplum*, *P. aff. longiconicum*, *Trillus elkhornensis*, and *Zartus* spp.

The base of this zone is marked by the lowest co-occurrence level of *T. elkhornensis* and species of the genus *Katroma*. In some sections, it is often difficult to distinguish Subzone IV from Subzone III.

The range of this zone is the Lower Jurassic (upper Pliensbachian to Toarcian?).

2. *Mesosaturnalis hexagonus* (Mh) Assemblage-zone (new)

The base of this zone is defined by the lowest occurrence of *Mesosaturnalis hexagonus* (= *Acanthocircus hexagonus* Yao) in associated with *Parvicingula nanoconica* Hori and Otsuka. This assemblage-zone is proposed for the interval between the Ps Assemblage-zone and the Pg Assemblage-zone.

The present author selected the IY Section (IY11-17) of the Inuyama area as the stratotype of this assemblage-zone and the following species including two diagnostic species, *M. hexagonus* and *P. nanoconica*, are characteristic in this zone. These are: *Ares (?) sp. D* (= *Parares sp. of Takemura, 1986*), *Hsuum altile* Hori and Otsuka, *H. sp. B* of Hori and Otsuka (1989), *H. sp. X* of Hori and Otsuka (1989), *H. (?) sp. Y* of Hori and Otsuka (1989), *Parahsuum simplum* Yao, *P. transiens* Hori and Yao, *P. (?) aff. magnum* Takemura, *P. (?) sp. B* of Hori and Otsuka (1989), *Parvicingula* cf. *gigantocornis* Kishida and Hisada, *Transhsuum medium* Takemura, *Trillus elkhornensis* Pessagno and Blome, *Napora* spp., *Tripocyclia* spp., and *Zartus* spp.

The range of this zone is the Lower Jurassic (Toarcian) to lower Middle Jurassic (Aalenian?).

Remarks: This zone was formerly named the *Acanthocircus hexagonus* Assemblage-zone (Hori, 1987, 1988). An assemblage reported from the Mt. Norikuradake area (Hori and Otsuka, 1989) is typical of this zone. In addition to the zonal index species, *M. hexagonus*, this zone is characterized by a nasselarian assemblage consisting mainly of the genera *Hsuum*, *Parahsuum (?)* and *Parvicingula* (s.l.). The first recorded occurrence of *Parvicingula* (s.l.) is observed at the base of this zone. These assemblages were reported by Matsuda and Isozaki (1982), and Kishida and Sugano (1982). Based on the co-

occurrence of conodonts and radiolarians, they tentatively assigned a latest Triassic to earliest Jurassic age. The recent radiolarian data indicate that this fauna is a late Early to early Middle Jurassic age.

3. *Parahsuum* (?) *grande* (Pg) Assemblage-zone

The base of this zone is defined by the lowest occurrence of *Parahsuum* (?) *grande* Hori and Yao in association with *P. transiens* Hori and Yao.

The present author selected the IY Section (IY18-24) and PT Section (PT5-8) of the Inuyama area as the stratotype. This assemblage-zone is characterized by the following species including a diagnostic species, *Parahsuum* (?) *grande* (= *P.* sp. D of Yao *et al.*, 1982): *Andromeda* sp. D of Yao *et al.* (1982), *Archicapsa pachyderma* (Tan Sin Hok), *Ares* (?) sp. D (= *Parares* sp. of Takemura, 1986), *Laxtorum* (?) *hichisoense* Isozaki and Matsuda, *L.* (?) *jurassicum* Isozaki and Matsuda, *Parahsuum simplum* Yao, *P. transiens* Hori and Yao, *P.* (?) aff. *magnum* Takemura, *P. nanoconica* Hori and Otsuka, *Stichocapsa* aff. *japonica* of Yao *et al.* (1982), *Transhsuum medium* Takemura, *Hsuum* sp. B of Hori and Otsuka, *H.* aff. *hisuikyoense* Isozaki and Matsuda, Nassellaria gen. et sp. indet. X, *Mesosaturnalis hexagonus* (Yao), *Napora* spp., *Tripocyclus* spp., *Unuma* (?) spp., and *Zartus* spp.

The range of this assemblage-zone is the upper Lower Jurassic (Toarcian?) to lower Middle Jurassic (Aalenian?).

Remarks: Yao *et al.* (1982) first reported the *Parahsuum* sp. D (= *P. grande*) Assemblage from the Inuyama area of the Mino Belt and the Kurosegawa area of the Chichibu Belt in SW Japan. Several species are common to the Mh Assemblage, however, the Pg Assemblage is distinguished by the occurrence of multisegmented nassellarians with a larger test, such as *Parahsuum* (?) *grande* and *Laxtorum* (?) *jurassicum*.

4. *Hsuum hisuikyoense* (Hh) Assemblage-zone

The base of this zone is defined by the lowest occurrence of *H. hisuikyoense* Isozaki and Matsuda in association with *L.* (?) *jurassicum* Isozaki and Matsuda. The top coincides with the base of the *Unuma echinatus* Assemblage-zone.

According to Yao *et al.* (1982) and others, this assemblage-zone is characterized by the following species including three diagnostic species, *Hsuum hisuikyoense* Isozaki and Matsuda, *Laxtorum* (?) *jurassicum* Isozaki and Matsuda, and *L.* (?) *hichisoense* Isozaki and Matsuda: *Archicapsa pachyderma* (Tan Sin Hok), *Dictyomitrella* aff. *kamoensis* Mizutani and Kido, *Eucyrtidiellum unumaense* (Yao), *Parvicingula* sp. C of Yao *et al.* (1982), *Mesosaturnalis hexagonus* (Yao), *Stichocapsa* aff. *japonica* Yao, *Tricolocapsa* (?) *fusiformis* Yao, *T.* cf. *ruesti* Tan Sin Hok, *Trillus elkhornensis* Pessagno and Blome, *Unuma* sp. A of Yao (1984), *Unuma* sp. C of Yao *et al.* (1982), *Zartus* sp. A of Yao *et al.* (1982), and *Zartus* cf. *dickinsoni* Pessagno and Blome.

The range of this assemblage-zone is the lower Middle Jurassic (Aalenian? to Bajocian).

Remarks: The *Hsuum* sp. B (= *H. hisuikyoense*) Assemblage was first recognized by Yao and Matsuoka (1981) in a siliceous mudstone of the Inuyama area. Yao *et al.* (1982), Yao (1983, 1984), and Isozaki and Matsuda (1985a, b) subsequently examined this assemblage and listed various characteristic species. Yao (1984) defined this assemblage-zone in the Kii-Yura area of the Chichibu Belt.

B. Age of assemblage-zones

In SW Japan, Lower and lower Middle Jurassic radiolarian fossils are very rarely associated with age-diagnostic species of other micro- and macro-fossils. Ages of radiolarian zones therefore are based on comparison of the Japanese faunas with other well dated radiolarians in North America and Turkey by taking into account their faunal or

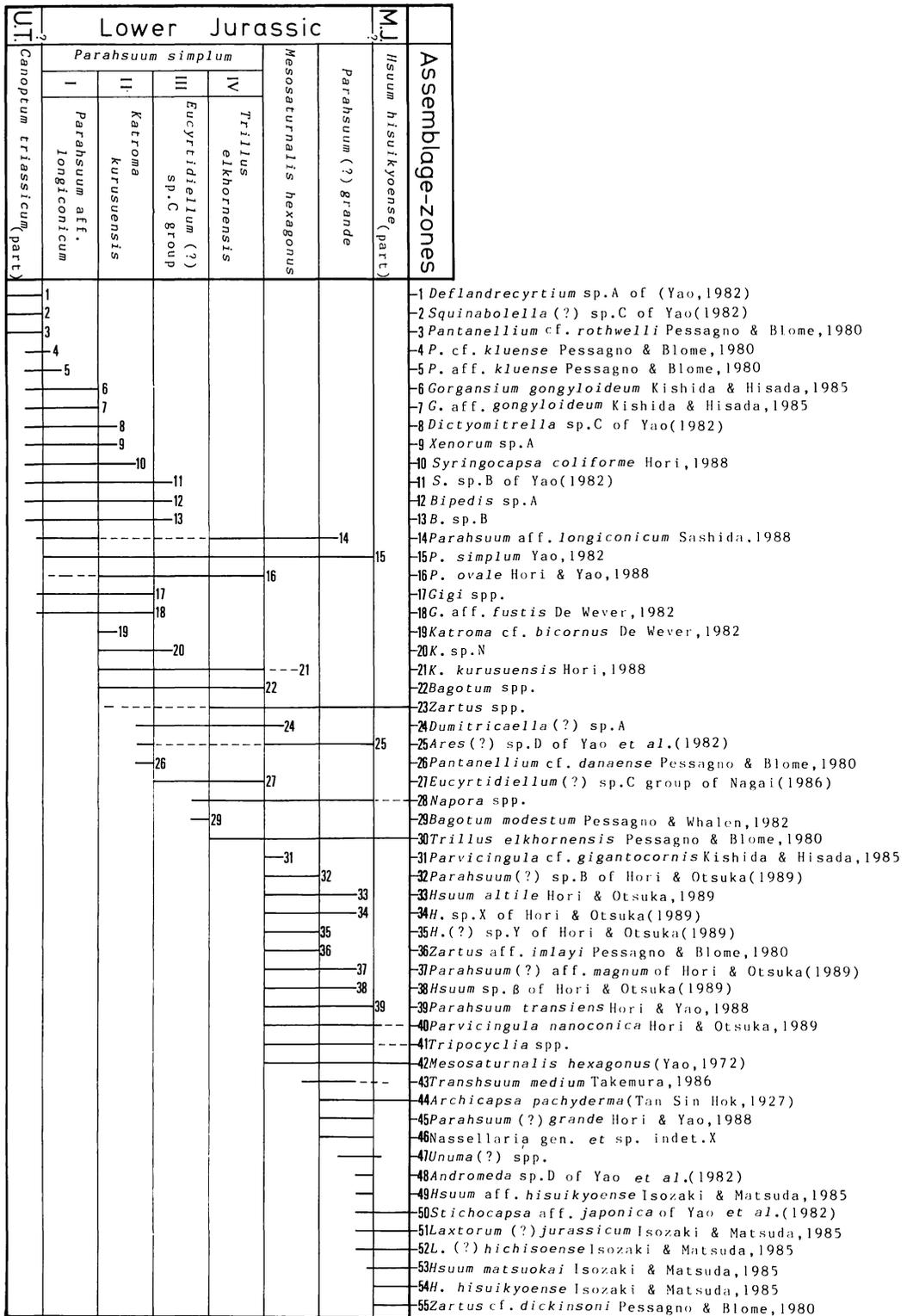


Figure 5. Radiolarian assemblage-zones for an upper Upper Triassic to lower Middle Jurassic sequence of SW Japan and range chart of selected radiolarians.

specific composition and relative stratigraphic positions.

When those four assemblage-zones described above are compared with radiolarian faunas from Lower and lower Middle Jurassic formations of the Queen Charlotte Islands in British Columbia, Canada, and those from east-central Oregon, U.S.A., three critical biohorizons can be dated. These are, (1) the base of the Ps Assemblage-zone; (2) the base of the Mh Assemblage-zone; and, (3) the top of the Hh Assemblage-zone.

Parahsuum simplicum Assemblage-zone: The Ps Assemblage-zone is probably dated as a Rhaetian/Hettangian?—late Pliensbachian and early Toarcian? age.

The base of the Ps Assemblage-zone can be placed in the Hettangian or lower horizon (Rhaetian) because of the following three constraints; 1) The lowest co-occurrence horizon of *Parahsuum simplicum* Yao and *Dictyomitrella* sp. C of Yao (1982) (=the basal boundary of this zone) lies below the first occurrence horizon of the genus *Katroma* Pessagno and Poisson emend. De Wever. According to Pessagno *et al.* (1987), its first occurrence defines the base of radiolarian Zone 04 where radiolarians are associated with lower Sinemurian ammonites in the Kunga Formation (=Sandilands Formation of Cameron and Tipper, 1985), Queen Charlotte Islands. These facts indicate that the base of this zone probably lies in the lower Sinemurian or lower. 2) The basal boundary of this zone lies a few meters above the final occurrence horizon of conodonts. In continuous chert sequence in the Inuyama area which crosses the Triassic-Jurassic boundary, the lower limit of this zone is always observed a few meters above the highest occurrence horizon of conodonts; this is representative the final occurrence of *Axiothea posthernsteini* (= *Misikella posthernsteini* Kozur and Mock) that occurs with such Triassic radiolarians as *Deflandrecyrtium* Kozur and Mostler and *Squinabolella* Kozur and Mostler. The highest occurrence of *A.*

posthernsteini was reported from the *Choristoceras marshi* Zone (uppermost Triassic; Rhaetian, or upper Upper Norian of Tozer, 1980) by Mostler *et al.* (1978). It is, therefore, highly probable that the basal boundary of this zone is within the Rhaetian or lowest Jurassic. 3) The basal boundary is below the final occurrence level of *Pantanellium* aff. *kluense* Pessagno and Blome. According to Pessagno and Blome (1980), *P.* aff. *kluense* occurs from the Rhaetian (?)/Hettangian part of the Kunga Formation (=Sandilands Formation of Cameron and Tipper, 1985) of the Queen Charlotte Islands.

Hori (1986) and Yao (1986) noted the co-occurrence of some characteristic species in this zone, *Bagotum* spp., *Canoptum* spp., *Katroma* spp., *Pantanellium* cf. *danaense* Pessagno and Blome and *Trillus* spp., and correlated this assemblage-zone with a interval from a part of the Sinemurian to Pliensbachian. Additionally, the base of the superjacent Mh Assemblage-zone is considered to be a middle Toarcian age, as discussed below. The top of the Ps Assemblage-zone, therefore, may extend upward to an early Toarcian age.

Mesosaturnalis hexagonus Assemblage-zone: Hori and Otsuka (1989) discussed the age of the Mh Assemblage. They inferred that its age ranges from late Early to early Middle Jurassic, at least including a certain interval of the Toarcian, based on their examination of a fauna representative of the Mh Assemblage which was recovered from the Mt. Norikuradake area.

Based on the following criteria, the Mh Assemblage-zone is assignable to a time interval between the Toarcian and Bajocian with its base definitively beginning the middle Toarcian.

Near the base of this zone, *Parvicingula* (s. l.) and *Mesosaturnalis hexagonus* make their first appearances. According to Carter *et al.* (1988), species of the genus *Parvicingula* (s. l.) are not found in the upper Pliensbachian to lower Toarcian Fannin Formation, but occur in the middle Toarcian Whiteaves Formation,

the middle to upper Toarcian and Aalenian Phantom Creek Formation, and the lower Bajocian Graham Island Formation, all of the Queen Charlotte Islands. They suggest that the first appearance of *Parvicingula* (s.l.) in the Queen Charlotte Islands occurs in middle Toarcian strata that are approximately equivalent to the *Hildoceras bifrons* Zone.

On the other hand, *Mesosaturnalis hexagonus* first occurs in the upper middle Toarcian part of the Phantom Creek Formation (upper *Haugia variabilis* to lower *Grammoceras thouarsense* Zones, in Carter *et al.*, 1988) of the Queen Charlotte Islands. These radiolarian data indicate the base of this zone to lie probably in the middle Toarcian.

The top of the Mh Assemblage-zone probably lies in the Middle Jurassic (Aalenian and/or Bajocian) because it always occupies a stratigraphic position between the underlying Ps Assemblage-zone (Rhaetian/Hettangian?—upper Pliensbachian) and the overlying Pg Assemblage-zone (possibly older than Bajocian age, as mentioned below) in all the continuous sequences in the Inuyama and other areas of SW Japan.

Parahsuum (?) *grande* Assemblage-zone: The exact age of the Pg Assemblage-zone is difficult to determine from a direct comparison with North American faunas due to the scarcity of species common to both these areas. Only the stratigraphic position of this zone, higher than the Mh Assemblage-zone and lower than the Hh Assemblage-zone, enables us to determine its approximate age. The Mh Assemblage-zone is probably correlatable with an upper Lower Jurassic to lower Middle Jurassic interval, at least including the middle Toarcian. The upper limit of the Hh Assemblage-zone may lie in the Bajocian (Isozaki and Matsuda, 1985b and in this paper). Thus, its age may be assigned to an interval from the middle Toarcian to Aalenian?

Hsuum hisuikyoenae Assemblage-zone: According to Isozaki and Matsuda (1985b), the lower part of the Hh Assemblage-zone is

probably of late Early to middle Middle Jurassic. The present author narrows a possible age of this zone to a shorter time interval between Aalenian? and Bajocian because of the following reasons. The *Unuma echinatus* (Ue) Assemblage, an assemblage immediately overlying the Hh Assemblage, is interpreted to be either Bajocian or Bathonian in age (Mizutani and Koike, 1982; Yao, 1986; Yokota and Sano, 1986, *etc.*). The upper limit of the Hh Assemblage-zone therefore can be datable as Aalenian or Bajocian in age. *Tricolocapsa* (?) *fusiformis* Yao is a characteristic species that occurs both in the Hh and Ue Assemblages-zones. According to Carter *et al.* (1988), this species is not found in the Pliensbachian to lower Aalenian Maude Group but occurs in the lower Bajocian part of the Yakoun Group (*Ovalis* Zone to lower? *Laeviuscula* Zone) of the Queen Charlotte Islands. Considering the stratigraphic data of these component taxons, the top of Hh Assemblage-zone can be drawn within an upper Aalenian to lower Bajocian interval.

On the other hand, the age of its base is difficult to place on the basis of faunal content. Because the Hh assemblage has few species in common with the late Toarcian to Aalenian fauna reported from North America, its stratigraphic position provides the only clue its age. This zone lies stratigraphically above the Pg Assemblage-zone. The Pg Assemblage-zone has not been dated precisely. The age of the subjacent Mh Assemblage-zone, however includes at least middle Toarcian time. Thus, the base of the Hh Assemblage-zone is believed to postdate the middle Toarcian.

C. Age of Subzones I-IV of the *Parahsuum simplum* Assemblage-zone

The age of Subzones I-IV ranges from latest Triassic/earliest Jurassic (Rhaetian/Hettangian?) to Early Jurassic (late Pliensbachian to Toarcian?). The base of the Ps Assemblage-zone agrees with the base of

Subzone I, while the upper boundary of the Ps Assemblage-zone coincides with the upper limit of Subzone IV. Other mutual boundaries between these subzones are marked by the first occurrences of some characteristic species belonging to the genera *Bagotum*, *Katroma* and *Trillus*. The oldest species of *Bagotum*, *B. erraticum* Pessagno and Whalen, is known from the Sinemurian part of the Kunga Formation (QC 549) (Pessagno and Whalen, 1982). Thus, the base of Subzone II is probably in the Sinemurian. According to Pessagno and Poisson (1981), and Pessagno and Blome (1980), the lowest horizon of co-occurrence of *Trillus elkhornensis* and species of the genus *Katroma* was found in the upper Pliensbachian Nicely Formation (*Amaltheus margaritatus* Zone-*Pleuroceras spinatum* Zone) (OR536) in east-central Oregon. The base of the Subzone IV, therefore, can lie in the upper Pliensbachian.

On the basis of these age constraints, Subzones I to IV are assigned to the following ages; I: Rhaetian/Hettangian?-Sinemurian?, II: Sinemurian-early Pliensbachian?, III: early Pliensbachian?-late Pliensbachian, IV: late Pliensbachian-early Toarcian?

Correlation of Lower Jurassic radiolarian zones

A. Correlation in Japan

In Japan, various radiolarian zones have been proposed for the Lower Jurassic interval after the first zonal description of Yao *et al.* (1980). Eight distinctive zonation schemes, five using assemblage-zones, (A2-A6) and three using other radiolarian biozones (B1-B3), are shown in Figure 6 along with the zonation presented in this paper (A1).

1. Correlation with zones of Matsuoka and Yao (1986): They proposed three radiolarian zones in the Lower Jurassic of SW Japan defined by biohorizons of the first or last appearance of characteristic species (Figure 6, B1).

The base of their *Parahsuum* sp. C (= *P.*

ovale) Zone roughly coincides with that of the present Ps Assemblage-zone. The *P. ovale* Zone seems to be a long-ranging zone and correlative with a combined intervals of the present Ps and Mh Assemblage-zones. Concerning the next younger *Archicapsa pachyderma* Zone, *A. pachyderma* (Tan Sin Hok) is found in the Pg Assemblage-zone but it lacks in the Mh Assemblage-zone. Matsuoka and Yao's this zone is a short ranging zone and correlated with a part of the Pg Assemblage-zone. Their *Laxtorum* (?) *jurassicum* Zone is correlative with the upper part of the Pg Assemblage-zone and the entire Hh Assemblage-zone.

2. Correlation with zones of Kishida and Sugano (1982), and Kishida and Hisada (1985, 1986): Kishida and Sugano (1982) studied some continuous sequences of chert and clastics in the Sakawa area in Shikoku of the Chichibu Belt and recognized four successive assemblage-zones for the uppermost Triassic and Lower Jurassic (Figure 6, A2). Subsequently, Kishida and Hisada (1985, 1986) revised these zones on the basis of early Jurassic radiolarian data obtained from a sedimentary complex in the Ueno-mura area of the Chichibu Belt. They recognized three assemblages and two subassemblages for the Lower Jurassic (Figure 6, A3).

Their *Bagotum pseudoerraticum* Assemblage-zone can be correlated with the Subzones I, II and III of the Ps Assemblage-zone based on its faunal composition. The *Katroma elliptica* Subassemblage-zone in their zonation is roughly attributable to the Subzone I because this subassemblage-zone contains *G. gongyloideum*, *P. aff. simplum* and species of the genus *Gigi* and lacks species of the genus *Katroma*. In their classification, the genus *Gigi* includes species belonging to the genus *Katroma*, e.g., *K. elliptica*. The *Wrangellium* (s.s.) Subassemblage-zone can be correlated with the Subzones II and III of the Ps Assemblage-zone judged by the presence of species of the genus *Katroma* and the absence of *Trillus elkhorn-*

nensis.

Their *Parvicingula gigantocornis* Assemblage-zone which is synonymous with their previous *Parvicingula* (?) sp. A-*Parvicingula* (?) sp. B Assemblage-zone, can be correlated to the Mh and a part of Pg Assemblage-zones on the basis of the first occurrence of the genus *Parvicingula* (s.l.).

The base of their *Spongocapsula* (?) sp. A Assemblage-zone can lie within the upper part of the Pg Assemblage-zone because *S.* (?) sp. A (= *Laxtorum* (?) *jurassicum*) first occurs in the upper part of the Pg Assemblage-zone. Kishida and Hisada (1986) equated the top of this zone with the base of the Ue Assemblage-zone (=the top of the Hh Assemblage-zone), however, it is questionable that the *S.* (?) sp. A Assemblage-zone can be correlated to the whole of the Hh Assemblage-zone due to lacking of characteristic species obtained from the upper part of the Hh Assemblage-zone.

3. Correlation with zones of Igo and Nishimura (1984): They documented four radiolarian assemblage-zones for an Upper Triassic to Lower Jurassic chert sequence of the "Aoyama Formation" in the Kuzuu area. They recognized two Lower Jurassic radiolarian assemblage-zones (Figure 6, A4).

Their *Parahsuum simplum-Gigi* sp. Assemblage-zone is correlative with the lower part of the Ps Assemblage-zone on the basis of species composition. Because their *Parahsuum* sp.-*Pantanellium* sp. Assemblage-zone was not fully documented in their paper, its upper boundary can not be correlated exactly with the zones presented in this paper.

4. Correlation with zones of Sashida and Igo (1985), Sashida *et al.* (1986) and Sashida (1988): Sashida and Igo (1985) and Sashida *et al.* (1986) recognized three successive radiolarian assemblage-zones for Lower Jurassic strata in the Kanto region of the Chichibu Belt (Figure 6, A5). Sashida (1988) later revised them and proposed four zones based on the radiolarian distribution in three sections in the Itsukaichi area of the Kanto

Mountains (Figure 6, B2).

Their *Parahsuum simplum* Zone is correlative with the Subzones I and II of the Ps Assemblage-zone of this paper judging from its species composition and stratigraphic position.

Sashida's (1988) *P. takarazawaense* Zone which corresponds to the *Bagotum* sp. A Zone includes *Trillus* aff. *elkhornensis* and *Eucyrtidiellum* sp. A (= *Eucyrtidiellum* (?) sp. C group in this paper). Thus, it can be correlative with the Subzones III and IV of the Ps Assemblage-zone.

His *Hsuum minoratum* Zone as defined by the first occurrence of *H. minoratum* at the base is roughly correlated with the Mh and a part of Pg Assemblage-zones, because abundant species of the genera *Hsuum* and *Parvicingula* are present.

The *Laxtorum* (?) *jurassicum* Zone of Sashida (1988) is considered to be coeval with the *Laxtorum* (?) *jurassicum* Zone of Matsuoka and Yao (1986).

5. Correlation with zones of Nishizono *et al.* (1982), Nishizono and Murata (1983), Sato and Nishizono (1983) and Sato *et al.* (1986): Nishizono *et al.* (1982), Nishizono and Murata (1983), and Sato and Nishizono (1983) investigated a radiolarian biostratigraphy of a Permian to Cretaceous sequence in the Kuma area of Kyushu and recognized 16 assemblages. Two radiolarian assemblages of Early Jurassic age were discriminated (Figure 6, A6).

Based on their species composition and stratigraphic position, their "*Archaeodictyomitra*" sp. A-*Triassocampe* sp. A Assemblage-zone and the "*Archaeodictyomitra*" *directiporata* -"*Eucyrtidium*" sp. A Assemblage-zone can be correlated with the combined intervals of the Subzone I and the lower part of Subzone III, and that of the part of Subzone III and Subzone IV of the Ps Assemblage-zone. For examples, the latter assemblage-zone is characterized by species of such genera *Napora*, *Trillus* and *Zartus*, "*Eucyrtidium*" sp. A and B (= *Eucyrtidium*

EAST ASIA				NORTH AMERICA				Chronostratigraphic units	
THIS STUDY Southwest Japan		Tikhomirova(1988) Far East U.S.S.R.	Vishinevskaya (1988) Far East U.S.S.R.	Murchey(1984) California	Pessagno et al. (1987) Composite	Carter et al. (1988) Queen Charlotte Is.			
<i>Hsuum hisuikyense</i>			J ₂	MH-2	Super-Zone 1 (part)	Zone 1B (part)	7	Baj (part)	M. J.R.
						Subzone 1A ₁	?	Aal	
↑ <i>Parahsuum(?) grande</i> ↓		?	J ₁ ²		Zone 1A (part)	Subzone 1A ₂	6		
↑ <i>Mesosaturnalis hexagonus</i> ↓						?	J ₁ ¹	Zone 01	
↑ <i>Trillus elkhornensis</i> ↓		R:3	J ₁ ¹	MH-1	Subzone 01A				4
↑ <i>Eucyrtidiellum (?) sp.C group</i> ↓						—	J ₁ ¹	Zone 02	Zone 03
↑ <i>Bagotum modestum</i> ↓		Droltus hecatensis	J ₁ ¹	Zone 04	Zone 05				
↑ <i>Katroma kurusuensis</i> ↓						R:2	Katroma (?) cf. bicornus	Zone 05	
↑ <i>Parahsuum aff. longiconicum</i> ↓		R:1	Archeocyrtum sp.A Archetypum sp.A						

Figure 7. International correlation of Lower Jurassic radiolarian zones in the circum-Pacific region. Chronostratigraphic units after Westermann (1985). The arrow represents possible range of zone.

(?) sp. C group) and “*Archaeodictyomitra*” *directiporata* (= *Parahsuum ovale* Hori and Yao, 1988).

Subsequently, Sato *et al.* (1986) proposed 13 new radiolarian zones for Lower Triassic to Upper Jurassic strata based on radiolarian data accumulated from Kyushu (Figure 6, B3). In their zonation, three range zones and one interval zone were defined for a Lower Jurassic to lower Middle Jurassic interval. The *Parahsuum* sp. A and *Parahsuum directiporata* Zones are equivalent with their previous “*Archaeodictyomitra*” sp. A–*Triasocampe* sp. A Assemblage-zone and the “*Archaeodictyomitra*” *directiporata* – “*Eucyrtidium*” sp. A Assemblage-zone, respectively. The former zones, therefore, can be correlated with the lower part of the Ps Assemblage-zone (Subzones I, II and a part of III) and the latter zone is correlatable with the upper part of the Ps Assemblage-zone (Subzone IV and a part of Subzone III) in this paper.

The *Droltus* (?) sp. A–*Droltus* (?) sp. G Zone is correlatable with the Mh and the lower part of the Pg Assemblage-zones based on this stratigraphic position.

Near the base of the *Hsuum* sp. G Zone, *Spongocapsula* (?) sp. A (= *Laxtorum* (?) *jurassicum*) makes its first appearance. The *Hsuum* sp. G Zone can, therefore, be correlated with a part of the Pg Assemblage-zone and the Hh Assemblage-zone.

B. International correlation

Several radiolarian zones proposed for a Lower Jurassic interval in the circum-Pacific region, particularly, zones established in the Queen Charlotte Islands and east-central Oregon are well dated by ammonites and other age diagnostic fossils. An international correlation of those Lower Jurassic radiolarian zones of Japan with those of East Asia and North America is summarized in Figure 7.

1. Correlation with zones of Pessagno *et al.* (1987): They established six radiolarian

zones for a Lower to lower Middle Jurassic (Hettangian to Aalenian?) interval, namely Zones 05, 04, 03, 02, 01, and 1A, in descending order.

The base of the Zone 05 is coincident with the first appearance level of *Pantanellium kluense* and the last that of *P. rothwelli*. In Japan, the highest co-occurrence of *P. cf. kluense* and *P. cf. rothwelli* is immediately below the base of the Ps Assemblage-zone. The base of the Zones 04 and 01 is defined by the first appearance of *Katroma* spp. and *Trillus elkhornensis*, respectively; these biohorizons correspond to the base of subzones II and IV of the Ps Assemblage-zone. The Zone 05, therefore, is correlated with the Subzone I, and the Zones 04 to 02 can be correlatable with the Subzones II and III of the Ps Assemblage-zone in SW Japan. The top of the Zone 01 is defined by the final appearance of *Praeconocaryomma parvimamma* as well as the first appearance of *Parvicingula* (s.l.), therefore, the Zone 01 can be correlatable with the Subzone IV of Japan.

The base of the Zone 1A is defined by the first appearance of the genus *Parvicingula* (s.l.). Judging from its stratigraphic position and radiolarian components, the Zone 1A can be correlated with the Mh Assemblage-zone and a part of the Hh Assemblage-zone of present study.

2. Correlation with zones of Carter *et al.* (1988): They proposed seven radiolarian zones, Zones 1 to 7, for upper Pliensbachian to lower Bajocian strata in the Queen Charlotte Islands. These zones have a short time span and their ages are well controlled by ammonite evidences. Because of the scarcity of species common to both Japan and Canada, these zones are occasionally difficult to correlate with the Japanese assemblage-zones. However, the Zones 1 and 6 may be correlative respectively with the Subzone IV of the Ps Assemblage-zone and with the Hh Assemblage-zone, based a comparison on the genus level.

The Zones 2 to 5 interval can be roughly

equated to the Mh Assemblage-zone based on the first occurrence of *Parvicingula* (s.l.) and *Mesosaturnalis hexagonus*.

The co-occurrence of *Tricolocapsa* (?) *fusififormis* and *Zartus jurassicus* was reported in the Zone 7. Therefore, it is probably attributable to the Hh Assemblage-zone.

3. Correlation with zones of Murchey (1984): She described seven radiolarian assemblages (Marin Headland Assemblages; MH-1 to MH-7) from a Jurassic-Cretaceous chert sequence in the Franciscan Complex, northern California, U.S.A.

The assemblage MH-1 includes species of the genera *Katroma*, *Napora* and *Eucyrtidium* (?), and *Bagotum* aff. *modestum*. In the upper part of this assemblage-zone, the first occurrence of *T. elkhornensis* is recognized. Hence, the MH-1 Zone is correlated with the upper part of the Ps Assemblage-zone (Subzones III to IV) in SW Japan.

The assemblage MH-2 includes *Parvicingula* sp. A (= *P. nanoconica*), *Mesosaturnalis hexagonus*, *Hsuum* sp. B (= *H. altile*), *T. elkhornensis*, *Napora* spp. and underlies the MH-3 Assemblage which is correlated with the *Unuma echinatus* Assemblage.

On the basis of its radiolarian composition and stratigraphic position, the MH-2 Assemblage-zone can be correlated with the Mh Assemblage-zone, the Pg Assemblage-zone and a part of Hh Assemblage-zone of SW Japan.

4. Correlation with zones of Tikhomirova (1988): Tikhomirova (1988) identified 12 radiolarian assemblages from Lower Jurassic to Lower Cretaceous strata along the Amur in the Khabarovsk region, central Sikhote-Alin

and in Primorye, Far East U.S.S.R. The following four assemblage-zones, R : 1, R : 2, R : 3 and R : 4, were established for an interval from Lower Jurassic to the lowest part of Middle Jurassic.

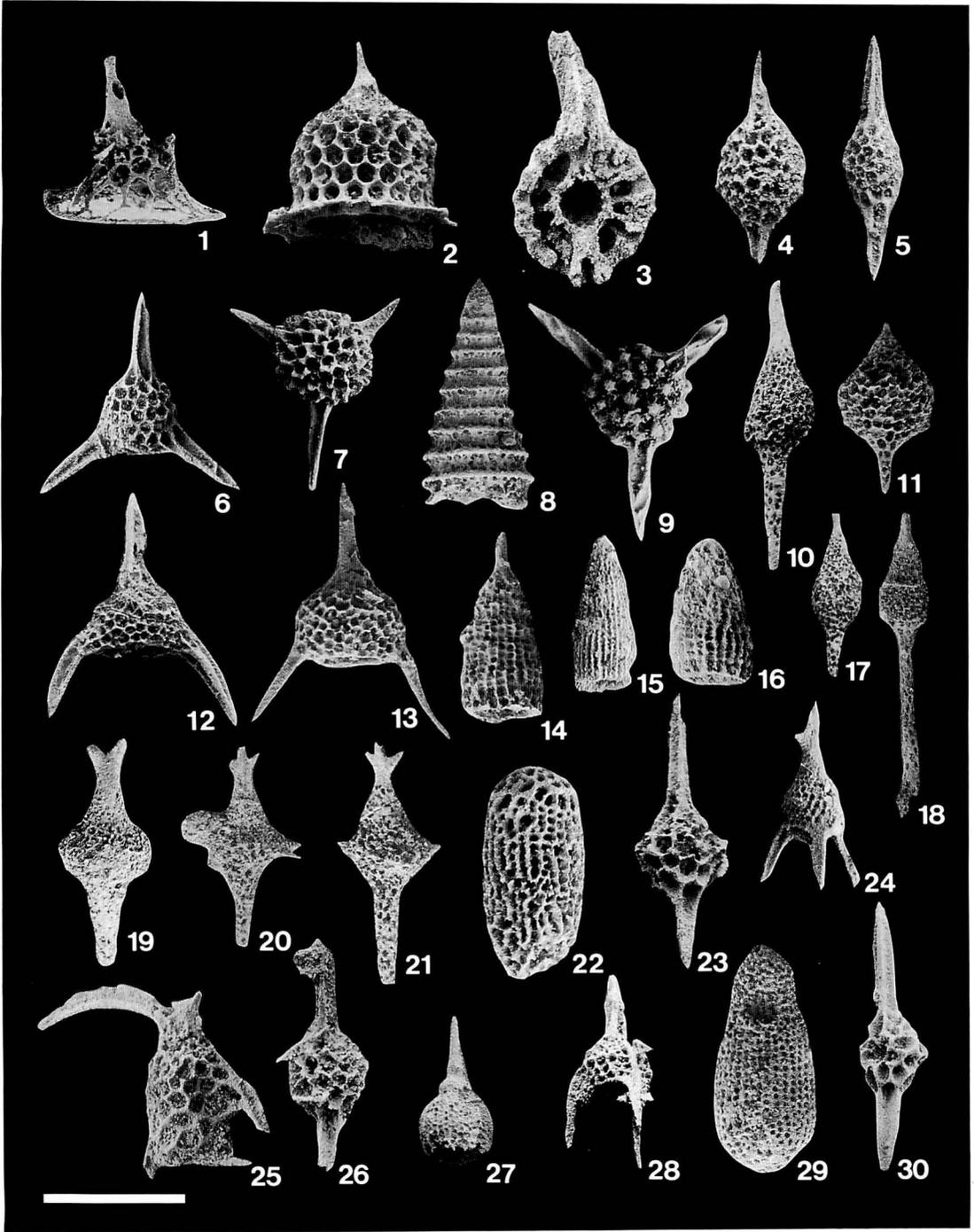
The R : 1 is characterized by *Archecyrtum* sp. A and *Archetypum* sp. A belonging to the family Archecyrtiidae Tikhomirova, 1987. These species have not been recognized in the Lower Jurassic strata in Japan, thereby making it difficult to correlate the R : 1 with Japanese zones. According to Tikhomirova (1988), the assemblage-zone is Hettangian in age based on its stratigraphic position, hence, it is tentatively correlated with the Subzone I of the Ps Assemblage-zone.

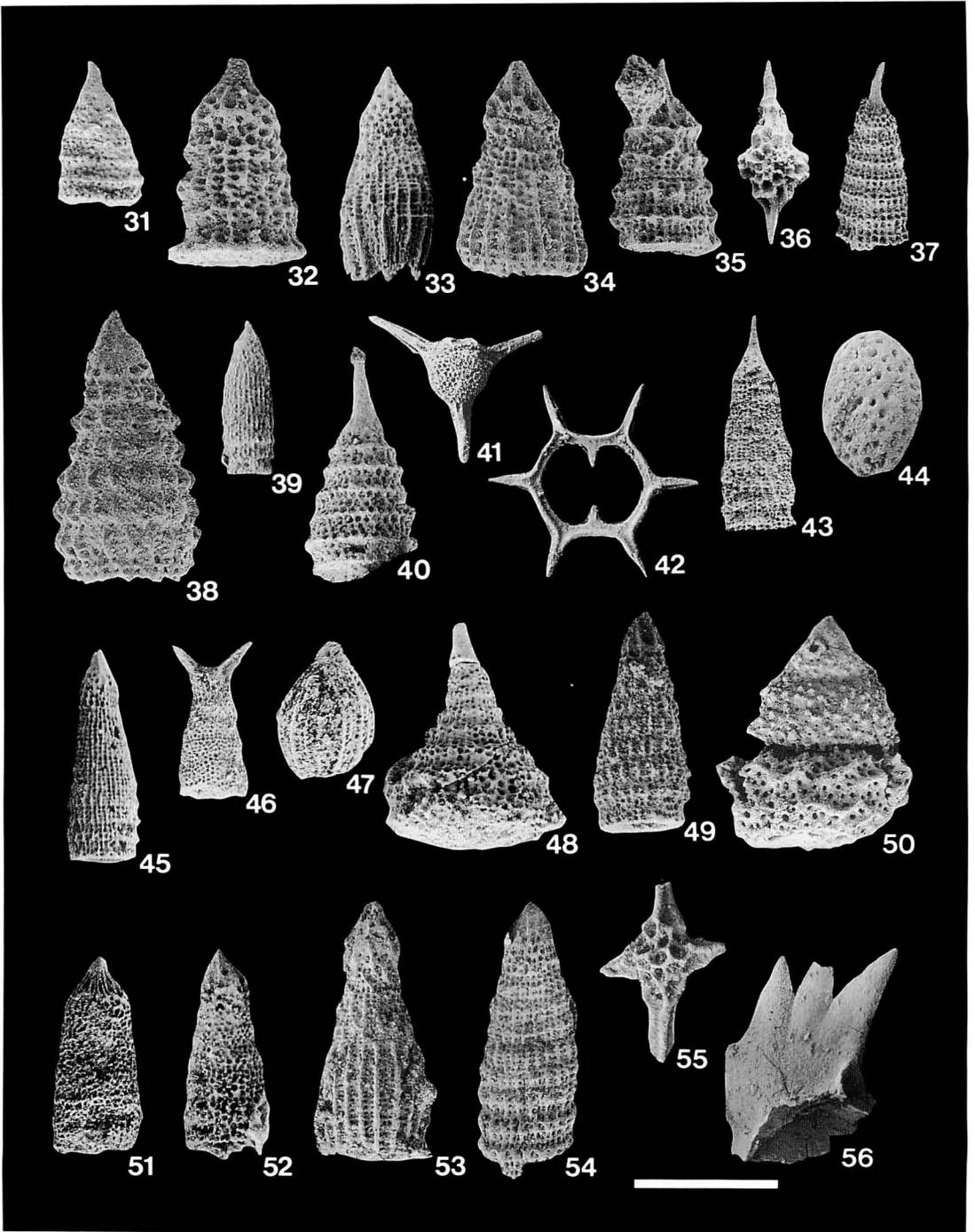
The R : 2 is characterized by *Katroma* (?) cf. *bicornus*, *Gigi fustis* and others. Species of the genera *Katroma* and *Gigi*, such as *Katroma* cf. *bicornus* and *Gigi* aff. *fustis*, co-occur in the Subzone II of the Ps Assemblage-zone of Japan, hence, the R : 2 is correlated with the Subzone II of the Ps Assemblage-zone.

The R : 3 is characterized by *Bagotum modestum* and *Droltus hecatensis*. *B. modestum* occurs in the Subzone III of the Ps Assemblage-zone of this paper. The R : 3, therefore, is roughly correlative to the upper part of the Ps Assemblage-zone, namely the Subzones III and IV. The R : 4 situated above the R : 3 is characterized by *Unuma typicus* and by lacking species of *Canoptum*, *Katroma*, *Gigi*, *Bagotum*, and *Droltus*. Therefore, the R : 4 can not be correlated with Lower Japanese ones because of the lacks of common species.

5. Correlation with the zones of Vishnevs-

→ **Figure 8.** Scanning electron micrographs of late Triassic to Early Jurassic radiolarians from the Mesozoic complex of SW Japan. Figure number corresponds to taxon number of 1 to 30 in Table 1 and Figure 5. Scale bar = 200 μm for all figures except for 17 (= 300 μm), 4, 23, 26, 29 (= 133 μm), and 3, 22 (= 100 μm). 1: *Deflandrecyrtium* sp. A, 2: *Squinabolella* (?) sp. C, 3: *Pantanellium* cf. *rothwelli*, 4: *P.* cf. *kluense*, 5: *P.* aff. *kluense*, 6: *Gorgansium gongyloideum*, 7: *G.* aff. *gongyloideum*, 8: *Dictyomitrella* sp. C, 9: *Xenorum* sp. A, 10: *Syringocapsa coliforme*, 11: *S.* sp. B, 12: *Bipedis* sp. A, 13: *B.* sp. B, 14: *Parahsuum* aff. *longiconicum*, 15: *P. simplum*, 16: *P. ovale*, 17: *Gigi* sp., 18: *G.* aff. *fustis*, 19: *Katroma* cf. *bicornus*, 20: *K.* sp. N, 21: *K. kurusuensis*, 22: *Bagotum* sp., 23: *Zartus* sp., 24: *Dumitricaella* (?) sp. A, 25: *Ares* (?) sp. D, 26: *Pantanellium* cf. *danaense*, 27: *Eucyrtidiellum* (?) sp. C group, 28: *Napora* sp., 29: *Bagotum modestum*, 30: *Trillus elkhornensis*.





kaya (1988): She established several radiolarian zones in the Jurassic to Paleocene formations of the Far East U.S.S.R. She recognized two Lower Jurassic radiolarian zones, J_1^2 and J_2^2 . Because both zones include species of the genera *Bagotum* and *Hsuum*, the boundary of J_1^2 and J_2^2 lies within the Pliensbachian. Judging from their radiolarian content, the J_1^2 Zone can be correlatable with the Subzones II, III and part of IV of the Ps Assemblage-zone. The J_2^2 Zone correlates with an interval from the uppermost part of the Ps (upper part of Subzone IV) to the Pg Assemblage-zones.

Conclusions

Four radiolarian assemblage-zones and four subzones are described for an uppermost Triassic/lowest Jurassic to lower Middle Jurassic interval. These are the *Parahsuum simplum* Assemblage-zone (divided into Subzones I through IV), *Mesosaturnalis hexagonus* Assemblage-zone, *Parahsuum* (?) *grande* Assemblage-zone, and *Hsuum hisuikyoense* Assemblage-zone (Figure 5). A correlation of these four zones with those proposed by earlier workers for the Japanese Lower Jurassic sequence is summarized in Figure 6.

The *Parahsuum simplum* Assemblage-zone is long-ranging spanning an interval from the Rhaetian? or Hettangian to early Toarcian?. In this assemblage-zone, four subzones (I, II, III and IV) are distinguished on the basis of radiolarian composition. They are correlat-

ed with other Lower Jurassic radiolarian zones proposed for the circum-Pacific region, for example the North American Zones 01 through 05 of Pessagno *et al.* (1987).

The *Mesosaturnalis hexagonus* Assemblage-zone, newly proposed in this paper, is an important Lower Jurassic biozone because its base coincides with the first appearance level of the genus *Parvicingula* (s.l.), which can be traced internationally.

One of the other zones, the *Hsuum hisuikyoense* Assemblage-zone is characterized by the fauna of the Middle Jurassic rather than the Lower Jurassic

The age of each zone is discussed by comparing them with the North American and Turkish faunas. Each zone spans an average interval of 5 m.y. within a time period from the latest Triassic/Early Jurassic to early Middle Jurassic.

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← **Figure 9.** Scanning electron micrographs of Early Jurassic to Middle Jurassic radiolarians, and a Late Triassic conodont (56) from the Mesozoic complex of SW Japan. Figure number corresponds to taxon number of 31 to 55 in Table 1 and Figure 5. 56: *Axiothea posthernsteini* (Kozur and Mock). Scale bar = 200 μm for all figures except for 41, 42 (= 300 μm), 31-35, 38, 40, 55 (= 133 μm), and 44, 47, 50, 56 (= 100 μm). 31: *Parvicingula* cf. *giganticornis*, 32: *Parahsuum* (?) sp. B, 33: *Hsuum altile*, 34: *H.* sp. X, 35: *H.* (?) sp. Y, 36: *Zartus* aff. *imlayli*, 37: *Parahsuum* (?) aff. *magnum*, 38: *Hsuum* sp. B, 39: *Parahsuum transiens*, 40: *Parvicingula nanoconica*, 41: *Tripocyclus* sp., 42: *Mesosaturnalis hexagonus*, 43: *Transhsuum medium*, 44: *Archicapsa pachyderma*, 45: *Parahsuum* (?) *grande*, 46: *Nassellaria* gen. et sp. indet. X, 47: *Unuma* (?) sp., 48: *Andromeda* sp. D, 49: *Hsuum* aff. *hisuikyoense*, 50: *Stichocapsa* aff. *japonica*, 51: *Laxtorum* (?) *jurassicum*, 52: *L.* (?) *hichisoense*, 53: *Hsuum matsukoi*, 54: *H. hisuikyoense*, 55: *Zartus* cf. *dickinsoni*. All the figured specimens in Figures 8, 9 were registered and deposited at the Department of Geosciences, Osaka City University.

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西南日本における下部ジュラ系放散虫化石帯: 西南日本のチャート及び泥岩からなる連続層序断面において放散虫化石の垂直分布を調査し, 4 群集帯と 4 亜群集帯を最上部トリアス系から中部ジュラ系下部の間に設定・記載した。記載した化石帯は, 下位より *Parahsuum simplum* 群集帯及びその 4 亜群集帯 (Subzones I-IV) と, *Mesosaturnalis hexagonus* 群集帯 (新提唱), *Parahsuum* (?) *grande* 群集帯, *Hsuum hisuikyoenense* 群集帯である。アンモナイト化石帯と直接対応のつく北米やトルコのデータとの比較により, 各群集帯の年代は, Rhaetian/Hettangian から Bajocian までの間にそれぞれ位置づけられる。新たに設定した *Mesosaturnalis hexagonus* 群集帯は, *Parvicingula* 属 (広義) の出現や多様な小型塔状 Nassellaria の産出で特徴づけられ, 西南日本だけでなく北米においても本群集帯に対応する化石帯が識別される。

堀 利栄

906. JURASSIC *EUCYRTIDIELLUM* (RADIOLARIA) IN THE MINO TERRANE*

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Abstract. Jurassic *Eucyrtidiellum* in chert, siliceous shale and manganese carbonate rock in the Mino terrane of central Japan was studied together with that of the Snowshoe Formation of Oregon with the result that eighteen species are recognized in the early Late to Upper Jurassic formations. Of all these species, *Eucyrtidiellum disparile*, *E. unumaense*, *E. pustulatum*, *E. semifactum* and *E. ptyctum* are most prevalent. These species are morphologically related with each other, and show an evolutionary trend composed of two consecutive steps of change, early in shell structure of abdomen, represented by transition from *E. disparile* to *E. unumaense* and later in superficial plication of abdomen, represented by transition from *E. pustulatum* through *E. semifactum* to *E. ptyctum*. On the basis of occurrence of *E. pustulatum* in the upper Bathonian part of the Snowshoe Formation, radiolarian biostratigraphical correlation for the Japanese Jurassic formations is discussed.

Two new species, *Eucyrtidiellum disparile* and *E. semifactum*, are described in this paper together with other species relevant to them.

Key words. *Eucyrtidiellum*, Jurassic, Mino terrane, Snowshoe Formation, radiolarian biostratigraphy, central Japan.

Introduction

We studied Jurassic radiolarians in the Mino terrane of central Japan, and recently focussed our attention upon morphological variation of *Eucyrtidiellum* in Middle to Late Jurassic time. Many species of this genus are commonly found in the following three assemblages, *i.e.*, Late Jurassic *Mirifusus baileyi* assemblage (Mizutani, 1981), late Middle Jurassic *Dictyomitrella* (?) *kamoensis-Pantanellium foveatum* assemblage (Mizutani and Kido, 1983) and middle Middle Jurassic *Unuma echinatus* assemblage

(Mizutani and Koike, 1982). Other species of older ages are also detected by Nagai (1988). In addition to our specimens, we also examined *Eucyrtidiellum* from the Snowshoe Formation of Oregon as a reference specimen whose horizon is biostratigraphically controlled by ammonites, and compared it with that of Japan. This paper summarizes all the data of *Eucyrtidiellum* available for us, and discusses its evolutionary trend found in Jurassic time.

Materials and localities

Skeletons of *Eucyrtidiellum* have been extracted from chert, siliceous shale and

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manganese carbonate rock collected from the Mino terrane of the Paleozoic-Mesozoic disrupted sedimentary complex in central Japan.

Rock samples of siliceous shale of Middle Jurassic age were obtained from Kutsuwano, Gifu Prefecture (137°0'46"E, 35°32'37"N) (Figure 1). Nagai (1987) extracted 281 specimens of *Eucyrtidiellum* from them. These rock samples were taken from a measured section about 10 m thick, in which *Pantanelium foveatum* Mizutani and Kido, *Dictyomitrella* (?) *kamoensis* Mizutani and Kido and *Tricolocapsa plicarum* Yao are contained. *Tricolocapsa conexa* Matsuoka is found in the lower part of the section. This siliceous shale is biostratigraphically referable to the *Dictyomitrella* (?) *kamoensis*-*Pantanelium foveatum* assemblage zone of Mizutani and Kido (1983).

Nagai (1986) also studied four rock sam-

ples of manganese carbonate nodule embedded in siliceous shale of Inuyama at the southeastern bank of Kiso River, Aichi Prefecture (136°57'51"E, 35°23'43"N) (Figure 1) and obtained 64 specimens of *Eucyrtidiellum* together with *Unuma echinatus* Ichikawa and Yao, *Zartus dickinsoni* Pessagno and Blome and others. The biostratigraphic horizon of these samples is believed to be equivalent to the manganese carbonate rock occurring at the northwestern bank of Kiso River, which was investigated by Mizutani and Koike (1982) to be correlative with the *Unuma echinatus* assemblage zone of the Middle Jurassic zonation.

Nagai (1988) also extracted 66 specimens of *Eucyrtidiellum* from a chert sample containing manganese micronodule exposed at Kamiaso, Gifu Prefecture (137°7'47"E, 35°32'52"N) (Figure 1). This rock sample contains *Laxtorum* (?) *jurassicum* Isozaki and Matsuda, *L.* (?) *hichisoense* Isozaki and Matsuda, *Hsuum hisuikyense* Isozaki and Matsuda, *H.* (?) *matsuokai* Isozaki and Matsuda and other radiolarians, all of them being indicative of late Early Jurassic or early Middle Jurassic age (Isozaki and Matsuda, 1985).

We also examined and comparatively studied many SEM photographs of *Eucyrtidiellum* in the Rad File of Nagoya University which were reported mainly from the Mino terrane of central Japan.

In addition to our specimens, we studied North American radiolarians in a filtrated residue obtained after chemical treatment of rock sample (OR-501C: provided by Pessagno of the University of Texas at Dallas). It was collected from the Snowshoe Formation, east central Oregon (Pessagno and Blome, 1982; Pessagno *et al.*, 1984), now registered in the Rad File of Nagoya University as JMP1617.

The Snowshoe Formation (Lupher, 1941; Dickinson and Vigrass, 1964, 1965) occurs in the Izee terrane (Silberling *et al.*, 1984), which is equivalent to the coherent terrane

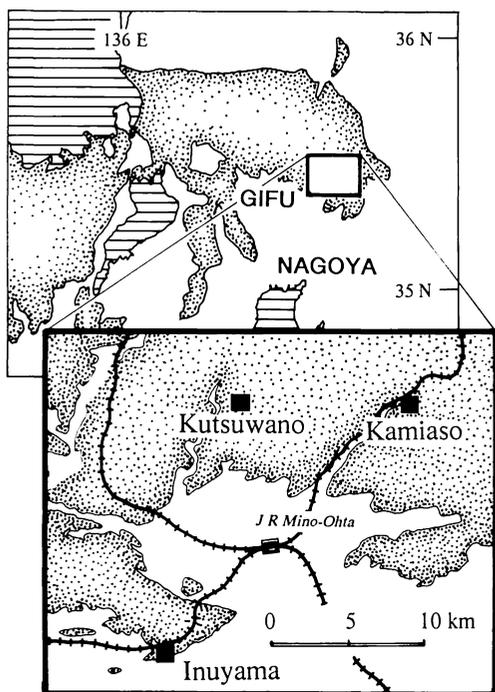


Figure 1. Sample localities in the Mino Terrane, central Japan. Dotted area: Paleozoic-Mesozoic disrupted sedimentary complex.

Table 1. Number of fossil bodies of Jurassic *Eucyrtidiellum* examined in this paper.

LOCALITY ⇒ <i>Eucyrtidiellum</i> ↓	KAMIASO Nagai (1988)	INUYAMA Nagai (1986)	SNOWSHOE OR-501C	KUTSUWASO (lower) Nagai (1987)	KUTSUWANO (upper) Nagai (1987)	others in Mino terrane	total
<i>E. disparile</i> Nagai and Mizutani, n. sp.	39	—	—	—	—	68	107
<i>E. gujoensis</i> (Takemura and Nakaseko)	—	5	—	—	—	6	11
<i>E. quinquatum</i> Takemura	—	—	—	—	—	—	—
<i>E. unumaense</i> (Yao)	—	53	—	3	42	218	316
<i>E. pustulatum</i> Baumgartner	—	—	11	6	124	70	211
<i>E. semifactum</i> Nagai and Mizutani, n. sp.	—	—	—	1	75	28	104
<i>E. nodosum</i> Wakita	—	—	—	2	10	12	24
<i>E. ptyctum</i> (Riedel and Sanfilippo)	—	—	—	—	4	28	32
<i>E. pyramis</i> (Aita)	—	—	—	—	—	3	3
<i>E. ozaiense</i> (Aita)	—	—	—	—	—	1	1
<i>E. sp. a₁</i> (Nagai, 1986)	5	2	—	—	—	33	40
<i>E. sp. a₂</i> (Nagai, 1986)	—	—	—	—	—	9	9
<i>E. sp. a₃</i> (Nagai, 1986)	—	3	—	—	—	2	5
<i>E. sp. d</i> (Nagai, 1986)	—	—	—	—	—	15	15
<i>E. sp. f</i> (Nagai, 1987)	1	—	1	—	2	5	9
<i>E. cf. nodosum</i> (Nagai, 1988)	21	—	—	—	—	3	24
<i>E. sp. A</i> (Aita and Okada, 1986)	—	—	—	—	—	—	—
<i>E. sp. C Group</i> (Nagai, 1986)	—	—	—	—	—	30	30
<i>E. sp.</i>	—	1	—	3	—	71	75
total number of bodies	66	64	12	15	257	602	1016

distinctly separated from the central mélange terrane in the Blue Mountains province of east Oregon (Dickinson and Thayer, 1978). The biostratigraphic position of OR-501 is most concisely summarized by Pessagno and Blome (1982) and by MacLeod (1988). In their locality descriptions, Pessagno and Blome (1982) wrote that OR-501A, B and C (the Upper member) are dark gray mudstone with common limestone nodules. Samples were taken from the limestone nodules immediately below the contact with overlying Trowbridge Formation. Imlay (1981) concludes in his discussion on the age of the Snowshoe Formation that the ammonite biostratigraphy makes possible a definite late Bathonian age assignment for the uppermost part of the Snowshoe Formation.

All these materials and their localities are summarized in Table 1 for ready comparison. In this table, the Kutsuwano samples are conveniently divided into two groups according to their stratigraphic position marked by the first appearance of *E. ptyctum*. The lower part does not include *E. ptyctum*. Of all the specimens of *Eucyrtidiellum* extracted from the Kutsuwano section, nine specimens were excluded in the present study, because their inner cephalic structure is quite different from that of *Eucyrtidiellum* (Nagai, 1989), even though their abdominal forms bear some resemblance to that of *E. disparile*.

A radiolarian fossil is always labeled like 44246/1543; the numerator indicates the registered number of SEM photograph of the radiolarian fossil and the denominator expresses the registered number of the rock sample from which the fossil was separated.

Morphological evolution of *Eucyrtidiellum*

Nagai (1988) summarized all the Japanese Jurassic species of *Eucyrtidiellum* so far described, and identified the following eight species to be included in this genus:

Eucyrtidium (?) *ptyctum* Riedel and Sanfilippo (Riedel and Sanfilippo, 1974).

E. (?) unumaense Yao (Yao, 1979)

E. pustulatum Baumgartner (Baumgartner, 1984)

E. (?) ozaiense Aita (Aita and Okada, 1986)

E. (?) pyramis Aita (Aita and Okada, 1986)

E. quinatum Takemura (Takemura, 1986)

E. gujoensis (Takemura and Nakaseko) (Takemura and Nakaseko, 1986)

E. nodosum Wakita (Wakita, 1988)

As will be described in the later section, the following two new species are also regarded as the Jurassic *Eucyrtidiellum*:

Eucyrtidiellum disparile Nagai and Mizutani, n. sp. (Figures 3-6-8).

E. semifactum Nagai and Mizutani, n. sp. (Figures 3-1-4).

Although they have not been exactly defined yet, the following five species, provisionally reported by Nagai (1986, 1987), also belong to the Jurassic *Eucyrtidiellum*: *E. sp. a₁*, *E. sp. a₂*, *E. sp. a₃*, *E. sp. d* and *E. sp. f*. *Eucyrtidiellum sp. a₁* resembles *E. disparile*, but it has very small relict pores on its abdomen. *E. sp. a₂* is also similar to *E. disparile*, but it has shorter ridge on the upper portion of its abdomen. *E. sp. a₃* has an abdomen with an oblique ridge up to the upper part, and this species is comparatively large in size. *E. sp. d* is very similar in its surface morphology to *E. nodosum* of the Upper Jurassic, but it differs in having pores on its entire abdomen. *E. sp. f* (Figure 4-8) has polygonal, usually hexagonal, pore frame on its abdomen and thorax. Nagai (1988) also reported many species of *E. nodosum* group (= *E. cf. nodosum* in Table 1). They are very similar to *E. nodosum*, but more or less differ in having more distinct nodes and having more spherical cephalis. We have the other group of Jurassic *Eucyrtidiellum*, such as *E. sp. A* (Aita and Okada, 1986, pl. 6, figs. 6-7), which is characterized by its conical shape and an annular and short abdomen, and *E. sp. C* group (Nagai, 1986, pl. 2, figs. 10-12), which has a different shell form. Since these seven

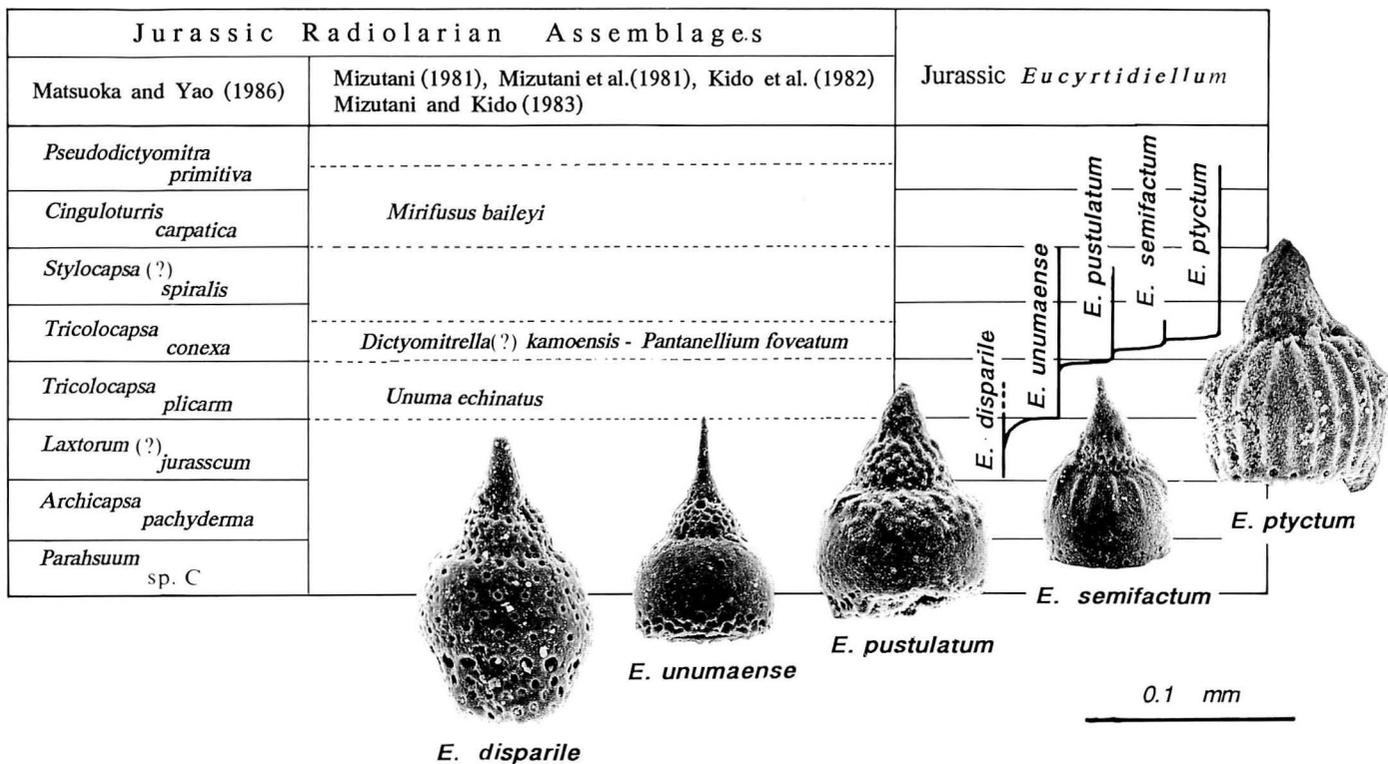


Figure 2. Jurassic *Eucyrtidiellum* and its morphological change in relation to the radiolarian assemblage zone in Japan. *E. disparile* (14773/194, Imajo area, after Nagai, 1986, pl. 1, fig. 5), *E. unumaense* (52833/1302, Inuyama, Nagai, unpublished), *E. pustulatum* (44240/1543, Kutsuwano, Nagai, unpublished), *E. semifactum* (44002/1531, Kutsuwano, this paper, Figure. 3-4a), and *E. ptyctum* (3498/108, Hida-Kanayama, after Mizutani, 1981, pl. 64, fig. 1a). Evolutionary trend of (i) change of shell structure of abdomen from *E. disparile* to *E. unumaense* in late Early Jurassic to middle Middle Jurassic interval, and (ii) development of superficial plication in abdomen from *E. unumaense* to *E. ptyctum* in middle Middle to late Jurassic interval.

species are relatively poorly found in the Jurassic radiolarian association, their mutual morphological relationship has not been clarified.

According to the Baumgartner's description, *Eucyrtidiellum* has a poreless thorax; however, there are many species which have a shell very similar in its external form to the type species (*Eucyrtidiellum unumaense*), but have pores in their thorax. These radiolarians are treated as *Eucyrtidiellum* in this paper, because of the similarity of their whole external form.

Thus, 18 species above cited are regarded as Jurassic *Eucyrtidiellum*, and their abundance in the Mino terrane is summarized together with that of the Snowshoe Formation in Table 1.

When arranged according to similarity of the external shell form of *Eucyrtidiellum*, two consecutive steps of morphological change (Figure 2) are recognized as was discussed previously by Nagai (1986): (1) change of shell structure of abdomen represented by transition from *Eucyrtidiellum disparile* to *E. unumaense* occurring in late Early Jurassic to middle Middle Jurassic interval, and (2) change of superficial plication in abdomen represented by transition from *E. unumaense* to *E. ptyctum* occurring in middle Middle to Late Jurassic interval.

The external shell form of *E. disparile* and that of *E. unumaense* are almost identical with each other, but they have different abdominal shell structure. The former has circular pores regularly arranged along two diagonal lines in its abdomen, whereas the latter has an abdomen of poreless and solid shell with smooth surface. An intermediate form between *E. disparile* and *E. unumaense* seems to be *E. sp. a₁* as reported by Nagai (1986). This species resembles *E. disparile*, but it should be noted that *E. sp. a₁* has very small relict pores on the surface of abdomen. *E. disparile* is commonly contained in the late Early or early Middle Jurassic sample of Kamiasso (Nagai, 1988). *E. sp. a₁* coexists

with *E. disparile*, but *E. unumaense* is not found there. On the other hand, *E. unumaense* is most prevalent in the middle Middle Jurassic sample of Inuyama (Nagai, 1986). A few bodies of *E. sp. a₁* also coexist with it. Occurrence of these species and their morphological properties reveal a successive change of shell structure particularly in its abdominal part.

The following six species were confirmed to occur together in the late Middle Jurassic section of siliceous shale in Kutsuwano, Gifu Prefecture: *E. pustulatum*, *E. semifactum*, *E. unumaense*, *E. nodosum*, *E. ptyctum* and *E. sp. f* as shown in Table 1. The external shell form of *E. pustulatum* resembles that of *E. unumaense*, but *E. pustulatum* has proximal portion of abdomen with nodes and pustules; its distal portion of abdomen is smooth. Similarly, the external shell form of *E. semifactum* resembles that of *E. ptyctum*, but *E. semifactum* has sixteen longitudinal short plicae on the upper one-fifth to two-thirds of the abdominal surface, and its plicae gradually die out downward leaving a smooth surface, while *E. ptyctum* has longitudinal plicae from the upper to the distal portion on the surface of abdomen. *E. unumaense* is abundant in the middle Middle Jurassic sample of Inuyama, but it is less abundant in the lower part of the Kutsuwano section and much less in the upper one (Table 1). *E. pustulatum* is prevalent in both parts of the Kutsuwano section, but *E. semifactum* is rare in the lower part and common in the upper one, where a few bodies of *E. ptyctum* appear.

This evidence supports above-mentioned morphological change of superficial plication; *i.e.* after the acme stage of *E. unumaense*, *E. pustulatum* proliferated and then it was replaced by *E. semifactum* and succeedingly by *E. ptyctum*. Morphological development of the other species is not so distinct as this group, probably owing to a random or spasmodic variation of their surface ornamentation.

Radiolarian biostratigraphical correlation

In the Snowshoe sample, *Eucyrtidiellum pustulatum* (Figures 4-4-5) is a common and only identifiable species of *Eucyrtidiellum*; a single body of *E. sp. f* (Figure 4-8) was detected in addition to *E. pustulatum* in the present study (Table 1). Since the geological age of the Snowshoe Formation has been defined as the late Bathonian by a comparative study of ammonites (Imlay, 1973, 1981), *E. pustulatum* is inferred to have proliferated in a stage of the late Bathonian in North America. This implies that the geological age of the Japanese formations where *E. pustulatum* is commonly included may well be assigned to the late Bathonian. As shown in Table 1, *E. unumaense* is very abundant in the Inuyama samples, and *E. pustulatum* has never been observed in them (Nagai, 1986). Judging from the occurrence of *Eucyrtidiellum* in the *Unuma echinatus* assemblage, it seems likely that *E. pustulatum* proliferated after the acme stage of *E. unumaense*, and the Japanese formation corresponding to the upper Bathonian lies above the *Unuma echinatus* assemblage zone.

The Kutsuwano section contains the radiolarian of the *Dictyomitrella* (?) *kamoensis-Pantanellium foveatum* assemblage accompanied with, in the order of relative abundance, *E. pustulatum*, *E. semifactum*, *E. unumaense*, *E. nodosum*, *E. ptyctum*, and *E. sp. f* (Nagai, 1987). The Kutsuwano and Oregon samples contain both of *E. pustulatum* and *E. sp. f*, but neither *E. semifactum* nor *E. ptyctum* was found in the Oregon sample. This suggests that *E. semifactum* and *E. ptyctum* proliferated at later ages. In fact, the upper part of the Kutsuwano section includes *E. semifactum* and *E. ptyctum*. Consequently, we conclude that the upper Bathonian part of the Japanese succession is located above the *Unuma echinatus* assemblage zone and below or in the lower portion of the *Dictyomitrella* (?) *kamoensis-Pantanellium foveatum* assem-

blage zone.

Conclusions

(1) Eighteen species of *Eucyrtidiellum* are recognized in the Jurassic *Eucyrtidiellum* in the Mino terrane, of which the following five are relatively abundant and identifiable: in the order of relative age, *E. disparile*, *E. unumaense*, *E. pustulatum*, *E. semifactum* and *E. ptyctum*.

(2) On the basis of the morphological variation of *Eucyrtidiellum*, an evolution composed of two consecutive steps is found, *i. e.*, from *E. disparile* to *E. unumaense*, and thereafter, from *E. unumaense* to *E. pustulatum*, *E. semifactum* and up to *E. ptyctum*.

(3) On the basis of the fact that *E. pustulatum* is exclusively found in the upper Bathonian part of the Snowshoe Formation, radiolarian biostratigraphical correlation can be made for the Japanese Jurassic formations as follows: the *Unuma echinatus* assemblage zone is lower than, and the lower part of the *Dictyomitrella* (?) *kamoensis-Pantanellium foveatum* assemblage zone is correlative with, the upper Bathonian.

Systematic description

- Subclass Radiolaria Müller, 1858
- Order Polycystina Ehrenberg, 1838,
emended Riedel, 1967
- Suborder Nassellaria Ehrenberg, 1875
- Polycystina incertae sedis
- Family Eucyrtidiellidae Takemura, 1986
- Genus *Eucyrtidiellum* Baumgartner, 1984

Type species.—*Eucyrtidium* (?) *unumaensis* Yao, 1979 (p. 39, pl. 9, figs. 1-11).

Remarks.—Before *Eucyrtidiellum* was defined by Baumgartner (1984), the Mesozoic species belonging to this genus had been questionably regarded and denoted as *Eucyrtidium* (?), because they bear no exact resemblance to the type species, *Eucyrtidium*

acuminatum Ehrenberg. According to the original description of *Eucyrtidium* (Foreman and Riedel, 1972), its test has segments with two or more strictures, and the type species (*Eucyrtidium acuminatum*) has eight segments. Contrary to this morphological definition, most, if not all, of the Mesozoic species have only three or four segments.

Baumgartner (1984) wrote in his original description that the shell of *Eucyrtidiellum* is composed of four segments, while Takemura (1986) noted that the shell is made up of more than four segments. The first segment, cephalis, is small, spherical or subspherical and poreless with an apical horn that is either straight or slightly curved and mostly small in size. The second segment, thorax, is dome-shaped and poreless in almost all species, and has ornamentation consisting of irregular ridges with depressions, nodes or plicae.

There are many pores at the stricture between the second and third segments. The third segment, abdomen, is inflated annular to hemispherical. Surface of the abdomen is generally smooth, but varies according to species; it is, for instance, pored or plicate. Post-abdominal segment is mostly cylindrical and may have a row of large pores on the stricture. There are only a few extant examples of the post-abdominal structure, because this segment is extremely delicate and easily disrupted.

Eucyrtidiellum disparile Nagai
and Mizutani, n. sp.

Figures 3-6—8a, b, c

- Eucyrtidium* (?) sp. a, Kido, 1982, pl. 5, fig. 5; Yamamoto, 1985, pl. 2, fig. 3.
Eucyrtidium (?) sp. A, Hattori and Yoshimura, 1982, pl. 4, fig. 2; Kojima, 1982, p. 83, pl. 1, fig. 12.
Eucyrtidium (?) sp. B, Hattori and Yoshimura, 1982, pl. 4, fig. 3.
Eucyrtidium (?) sp., Hattori and Yoshimura, 1983, pl. 9, fig. 11.
Eucyrtidiellum sp. A, Mizugaki, 1985, pl. 45, fig. 9; Hattori, 1987, pl. 12, figs. 1-2; Hattori, 1988a, pl. 8, fig. D.

- Eucyrtidiellum* sp. a, Nagai, 1986, pl. 1, fig. 5; Nagai, 1988, pl. 1, figs. 1a-d, 2.
Eucyrtidiellum sp. a₁, Nagai, 1986, pl. 1, fig. 6.
Monosera unumaensis Takemura and Nakaseko, 1986, p. 1022, figs. 4.9.
Eucyrtidiellum (?) sp. X, Hattori, 1987, pl. 12, fig. 16.
Eucyrtidiellum sp., Hattori, 1988b, pl. 1, fig. J.

Diagnosis.— Abdomen has circular pores regularly arranged along two diagonal lines on its whole surface.

Description.— This species has a test which is composed generally of three segments, cephalis, thorax and abdomen. Cephalis is small, spherical with a medium-sized apical horn. Sutured pores are arranged at a stricture between thorax and abdomen. Thorax truncated-conical with closed pores and irregular hexagonal meshworks on the whole surface. Abdomen is relatively large and inflated-hemispherical, with circular pores regularly arranged along two diagonal lines on its whole surface.

Measurements.— (in μm , based on 10 specimens): height of apical horn, 3-13 (average 8); height of entire body including cephalis, thorax and abdomen, 67-100 (average 79); height/width of cephalis, 5-19 (average 13)/8-21 (average 17); height/width of thorax, 14-23 (average 18)/31-38 (average 35); height/width of abdomen, 41-66 (average 48)/48-77 (average 71).

Remarks.— External shell form of *Eucyrtidiellum disparile* is almost identical with that of *E. unumaense*, but differs in having pores on its entire abdomen. Many specimens of *Eucyrtidiellum* have been provisionally described as *Eucyrtidium* (?) sp. or *Eucyrtidiellum* (?) sp., just because of the presence of opened pores in their abdomen.

Etymology.— Derived from Latin adjective “*disparilis*, -e”, which means “unlike” or “dissimilar”.

Occurrence.— Common in siliceous shale of late Early Jurassic to Middle Jurassic age of Kamiasso, Gifu Prefecture.

Repository.— Holotype, HNHK05-C3-46 (Figures 3-8a, b, c; 45946/1467, 45948/1467,

50409/1467), Paratype, HNHK05-C3-41 (Figure 3-6; 45932/1467), and HNHK03-A3-44 (Figure 3-7; 42536/1467); stored in the Rad File, Nagoya University.

Eucyrtidiellum semifactum Nagai
and Mizutani, n. sp.

Figures 3-1—4a, b

- Eucyrtidium* (?) sp. b, Kido *et al.*, 1982, p. 201, pl. 4, figs. 10-11; Yamamoto, 1985, pl. 2, fig. 9.
Eucyrtidium (?) sp. A, Wakita, 1982, pl. 3, fig. 2.
Eucyrtidium? sp. aff. *E.?* *ptyctum* Riedel and Sanfilippo, Sato *et al.*, 1982, pl. 4, fig. 4.
Eucyrtidiellum sp. b, Nagai, 1986, pl. 2, fig. 6; Nagai, 1987, pl. 3, figs. 1a, b, 2; Nagai, 1988, pl. 2, figs. 3a, b.
Eucyrtidiellum sp. b₁, Nagai, 1986, pl. 2, fig. 3.
Eucyrtidiellum sp. b₂, Nagai, 1986, pl. 2, fig. 4.
Eucyrtidiellum sp. b₃, Nagai, 1986, pl. 2, fig. 5.
Eucyrtidiellum sp. B, Hattori, 1987, pl. 12, fig. 8.
Eucyrtidiellum sp. B₂, Hattori, 1987, pl. 12, fig. 9.
Eucyrtidiellum sp., Kojima and Mizutani, 1987, fig. 4; 14-15; Kojima, 1989, pl. 2, 6a, b.

Diagnosis.—Abdomen has sixteen longitudinal but short plicae on the upper one-fifth to two-thirds of the surface.

Description.—Test usually composed of cephalis, thorax and abdomen. Cephalis is small, spherical with a small or medium-sized apical horn. Thorax truncated-conical with closed pores on the whole surface. Sutured pores are arranged at a collar stricture between thorax and abdomen. Third segment, abdomen, is poreless having sixteen longitudinal but short plicae on the upper one-fifth to two-thirds of the segment. The plicae gradually die out downward leaving a smooth surface, with a few very small pores at distal portion.

Measurements.—(in μm , based on 10 specimens): height of apical horn, 5-18 (average 9); height of entire body including cephalis, thorax and abdomen, 56-82 (average 72); height/width of cephalis, 8-15 (average 11)/10-21 (average 15); height/width of thorax, 13-21 (average 16)/26-33 (average 29); height/width of abdomen, 36-49 (average

46)/62-69 (average 67).

Remarks.—This species resembles *E. ptyctum*, but differs in having shorter plicae on its abdominal surface. *E. semifactum* is found not infrequently in the Jurassic of the Japanese Islands.

Etymology.—Named after Latin adjective “*semifactus*, -a, -um” meaning “half-done” or “half-finished”.

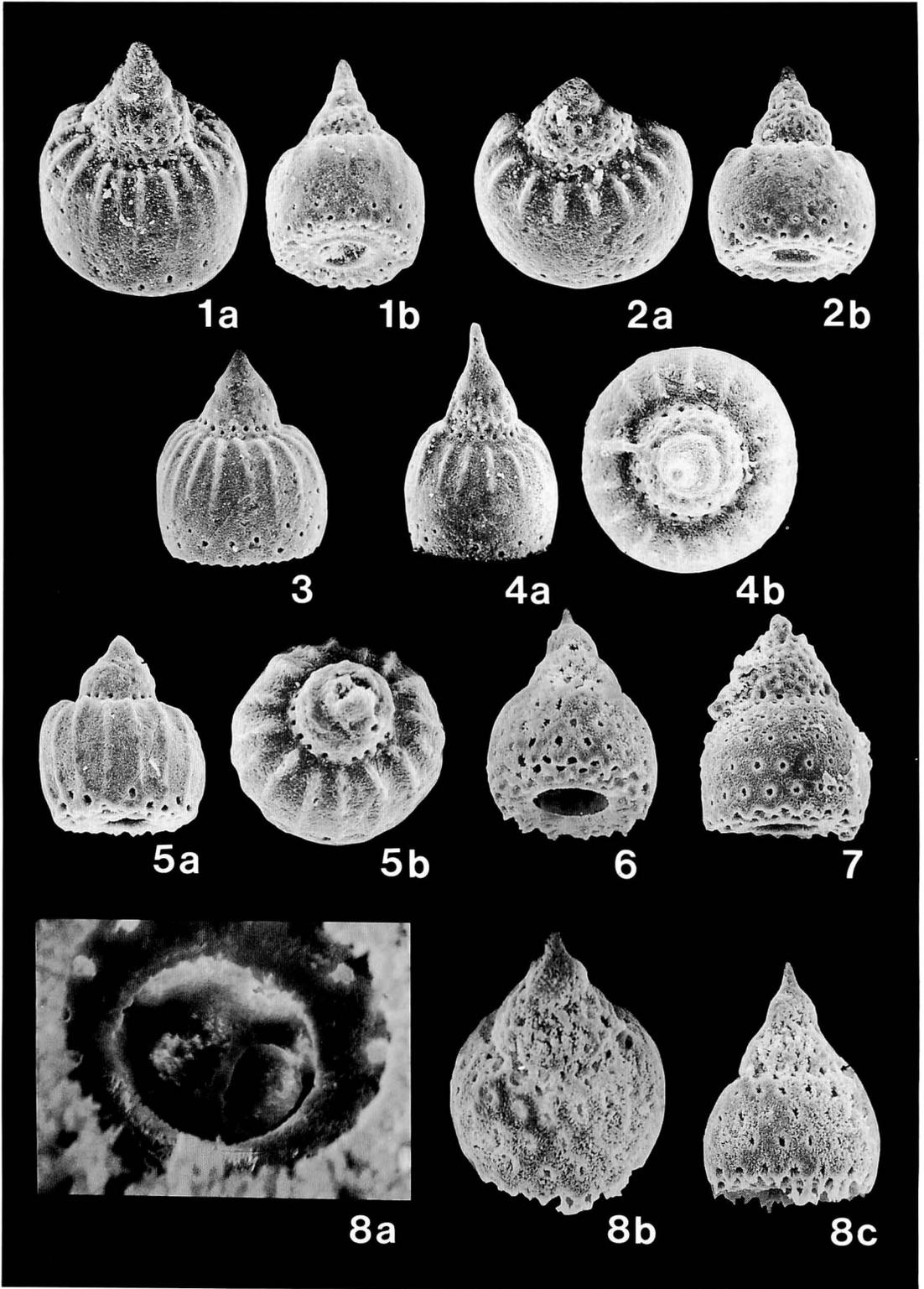
Occurrence.—Siliceous shale of Middle Jurassic age of Kutsuwano, Gifu Prefecture.

Repository.—Holotype, HNHK05-B4-52 (Figures 3-1a, b; 44246/1543, 44245/1543), Paratype, HNHK05-B4-55 (Figure 3-3; 44249/1543), HNHK05-B1-35 (Figures 3-2a, b; 44132/1540, 44131/1540), and HNHK04-D5-62 (Figures 3-4a, b; 44002/1531, 44001/1531); stored in the Rad File, Nagoya University.

Eucyrtidiellum ptyctum (Riedel
and Sanfilippo, 1974)

Figures 3-5a, b

- Eucyrtidium ptyctum* Riedel and Sanfilippo 1974, p. 778, pl. 5, fig. 7, pl. 12, figs. 14-15; Baumgartner and Bernoulli, 1976, p. 617, figs. 11e-g; Baumgartner *et al.*, 1980, p. 53 pl. 3, fig. 13; Aita, 1982, pl. 2, figs. 8, 9a, b; Nishizono *et al.*, 1982, pl. 2, fig. 12; Yao, 1984, pl. 2, fig. 30.
Eucyrtidium (?) *ptyctum* Riedel and Sanfilippo, Pessagno, 1977, p. 94, pl. 12, fig. 7; Foreman, 1977, pl. 2, fig. 5; Mizutani, 1981, p. 182, pl. 64, figs. 1a, b-2; Adachi, 1982, pl. 3, figs. 7-8; Okamura and Uto, 1982, pl. 6, fig. 18; Mizutani *et al.*, 1982, p. 57, pl. 4, fig. 5; Ishida, 1983, pl. 9, fig. 4; Nakaseko *et al.*, 1983, fig. 2: 12; Yamamoto, 1983, pl. 1, fig. 4; Takashima and Koike, 1984, pl. 2, fig. 5; Aita, 1985, fig. 7: 14; Matsuoka and Yao, 1985, pl. 2, fig. 8; Matsuoka and Yao, 1986, pl. 2, fig. 10; Tanaka *et al.*, 1985, pl. 1, fig. 16; Aita and Okada, 1986, p. 109, pl. 6, figs. 14-17, pl. 7, figs. 3a, b.
Eucyrtidium? *ptyctum* Riedel and Sanfilippo, Nishizono and Murata, 1983, pl. 4, fig. 7; Ishida, 1985, pl. 3, fig. 15.
Eucyrtidiellum ptyctum (Riedel and Sanfilippo) Baumgartner, 1984, p. 764, pl. 4, figs. 1-3; Matsuoka, 1986, pl. 2, fig. 10; Nagai, 1986, p. 14, 15, pl. 2, fig. 7; Aita, 1987, pl. 4, figs. 12a, b, pl. 10, fig. 14, pl. 14, fig. 3; Kojima and Mizutani, 1987, p. 260, fig. 4: 12-13; Nagai, 1987, pl. 3, figs. 5a-c, 6;



Nagai, 1988, pl. 2, figs. 4a, b; Wakita, 1988, pl. 4, fig. 28, pl. 5, fig. 17; Kojima, 1989, pl. 2, figs. 7a, b. "*Eucyrtidium*" *ptyctum* Riedel and Sanfilippo, Pesagno *et al.*, 1984, p. 30-31, pl. 4, figs. 12-14.

Eucyrtidiellum pustulatum Baumgartner

Figures 4-1—5a, b, c

Eucyrtidiellum pustulatum Baumgartner, 1984, p. 765, pl. 4, figs. 4-5; Yamamoto *et al.*, 1985, pl. 4, figs. 4-5; Nagai, 1986, p. 14, pl. 2, fig. 2; Aita, 1987, pl. 4, figs. 13a-14b, pl. 10, figs. 15-16; Nagai, 1987, pl. 2, figs. 2a-c, 3a, b, 4a, b; Nagai, 1988, pl. 2, figs. 2a, b; Wakita, 1988, pl. 4, figs. 26-27.

Eucyrtidium sp., Sashida *et al.*, 1982, pl. 1, fig. 3.

Eucyrtidium (?) *unumaense* Yao, Aita, 1985, fig. 7: 15-16.

Eucyrtidiellum unumaense (Yao, 1979)

Figures 4-6—7

Stichocorys sp., Ichikawa and Yao, 1973, pl. 1, figs. 3-4a, b.

Eucyrtidium (?) *unumaensis* Yao, 1979, p. 39, pl. 9, figs. 1-11; Sugano *et al.*, 1980, pl. 4, fig. 3; Hattori and Yoshimura, 1982, pl. 4, fig. 1; Kido *et al.*, 1982, pl. 4, fig. 9; Kojima, 1982, pl. 1, fig. 11; Sashida *et al.*, 1982, pl. 2, fig. 3; Wakita, 1982, pl. 3, fig. 1; Wakita and Okamura, 1982, pl. 8, fig. 7; Saka, 1983, pl. 5, figs. 6, 7.

Eucyrtidiellum unumaensis (Yao), Baumgartner, 1984, pl. 4, fig. 6; Yamamoto *et al.*, 1985, pl. 4, fig. 6; Mizugaki, 1985, pl. 45, fig. 10; Takemura, 1986, p. 67, pl. 12, figs. 10-12; Nagai, 1986, p. 13, 14, pl. 1, figs. 1a-c, pl. 2, fig. 1; Gorican, 1987, p. 182, pl. 3, figs. 9-10; Hattori, 1987, pl. 12, fig. 7; Wakita, 1988, pl. 3, fig. 15; Hattori, 1988a, pl. 8, fig. 1.

Eucyrtidium (?) *unumaense* Yao, Mizutani *et al.*, 1984, pl. 1, fig. 8; Yamamoto, 1985, pl. 2, fig. 4.

Eucyrtidiellum unumaense (Yao, 1979), Kojima and

Mizutani, 1987, p. 260, pl. 4, fig. 16; Nagai, 1987, pl. 2, figs. 1a-c; Yao, 1987, p. 95; Nagai, 1988, pl. 2, figs. 1a, b; Wakita, 1988, pl. 4, fig. 25; Kojima, 1989, pl. 2, figs. 5a, b.

Monosera unumaensis (Yao), Takemura and Nakaseko, 1986, p. 1021, fig. 4.8.

Unnamed nassellariinid, Jones *et al.*, 1980, pl. 2, fig. 14.

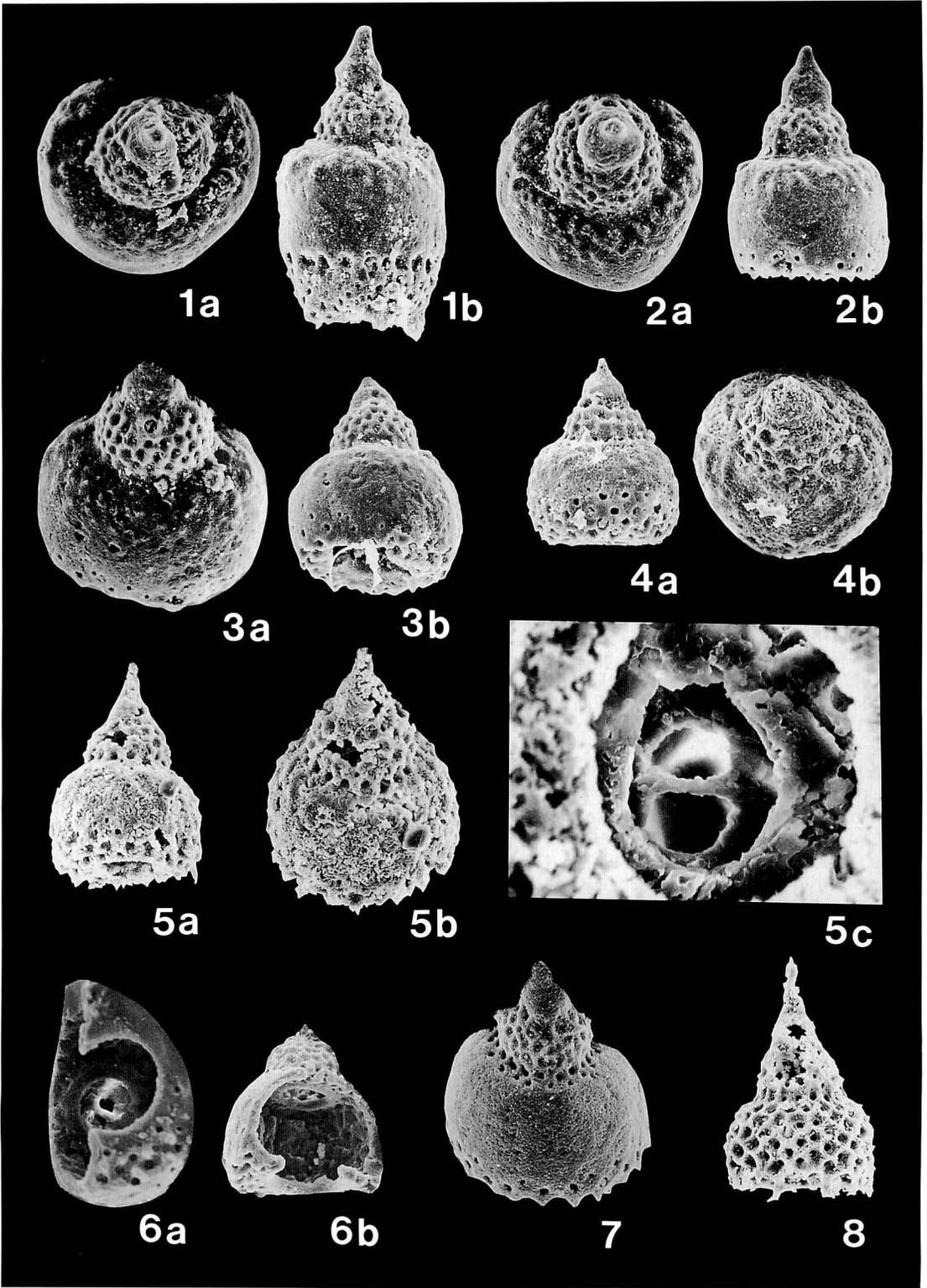
Eucyrtidiellum sp. f

Figure 4-8

Nagai, 1987, pl. 2, figs. 5a, b; Nagai, 1988, pl. 2, figs. 8a, b.

Descriptive remarks.—Cephalis small, spherical with a small apical horn. Thorax truncated-conical. Hexagonal pore frame developed on thorax and abdomen on the whole surface. This species is characterized by its distinct poreframe; it may well be defined as a new species of *Eucyrtidiellum*. However, the species is relatively rare in our rock-samples, and hence it is tentatively described in this paper as that of Nagai (1987). Result of measurements is as follows (in μm , based on 3 specimens): height of apical horn, 3-10 (average 4); height of cephalis, thorax and abdomen, 54-69 (average 62); height/width of cephalis, 8-15 (average 10)/15-18 (average 17); height/width of thorax, 13-18 (average 15)/31-36 (average 33); height/width of abdomen, 33-38 (average 36)/59-72 (average 64).

← **Figure 3.** 1-4, *Eucyrtidiellum semifactum* Nagai and Mizutani, n. sp. from Kutsuwano. 1, (Holotype, HNHK05-B4-52), 1a, Upper oblique view (after Nagai, 1987, pl. 3, fig. 1b, 44246/1543) $\times 500$, 1b, Lateral view (*Ibid.*, pl. 3, fig. 1a, 44245/1543) $\times 390$. 2, (Paratype, HNHK05-B1-35), 2a, Upper oblique view (44132/1540) $\times 500$, 2b, Lateral view (44131/1540) $\times 390$. 3, (Paratype, HNHK05-B4-55), Lateral view (*Ibid.*, pl. 3, fig. 2, 44249/1543) $\times 390$. 4, (Paratype, HNHK04-D5-62), 4a, Lateral view (44002/1531) $\times 390$, 4b, Upper oblique view (44001/1531) $\times 500$. 5, *Eucyrtidiellum ptyctum* Riedel and Sanfilippo from Kutsuwano. 5a, Lateral view (*Ibid.*, pl. 3, fig. 5a, 43892/1528) $\times 390$, 5b, Upper oblique view (*Ibid.*, pl. 3, fig. 5b, 43893/1528) $\times 500$. 6-8, *Eucyrtidiellum disparile* Nagai and Mizutani, n. sp. from Kamiaso. 6, (Paratype, HNHK05-C3-41), Lateral view (45932/1467) $\times 390$. 7, (Paratype, HNHK03-A3-44), Lateral view (42536/1467) $\times 390$. 8, (Holotype, HNHK05-C3-46), 8a, Closeup of cephalic structure (after Nagai, 1988, pl. 1, fig. 1c, 45946/1467) $\times 1770$, 8b, Upper oblique view (*Ibid.*, pl. 1, fig. 1d, 45948/1467) $\times 500$, 8c, Lateral view (50409/1467) $\times 390$.



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← **Figure 4.** 1-3, *Eucyrtidiellum pustulatum* Baumgartner from Kutsuwano. **1a**, Upper oblique view (43966/1530) × 500, **1b**, Lateral view (43965/1530) × 390. **2a**, Upper oblique view (after Nagai, 1987, pl. 2, fig. 2b, 43952/1530) × 500, **2b**, Lateral view (*Ibid.*, pl. 2, fig. 2a, 43952/1530) × 390. **3a**, Upper oblique view (44023/1532) × 500, **3b**, Lateral view (44022/1532) × 390. 4-5, *Eucyrtidiellum pustulatum* Baumgartner from the Snowshoe Formation (OR-501C). **4a**, Lateral view (48374/1617) × 390, **4b**, Upper oblique view (48377/1617) × 500, **5a**, Lateral view (48380/1617) × 390, **5b**, Upper oblique view (48382/1617) × 500, **5c**, Closeup of cephalic structure (47063/1617) × 1770. 6-7, *Eucyrtidiellum unumaense* (Yao). **6a**, Cephalic structure (41670/1300) × 500, **6b**, Lateral view (41671/1300) × 390. **7**, Upper oblique view (44059/1532) × 500. **8**, *Eucyrtidiellum* sp. f from the Snowshoe Formation (OR-501C). Lateral view (48384/1617) × 390.

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Inuyama 犬山, Kamiaso 上麻生, Kutsuwano 轡野, Mino 美濃.

美濃帯の放射虫化石 *Eucyrtidiellum*: 中部日本美濃帯のチャート, 珪質頁岩, マンガン炭酸塩岩から得られた *Eucyrtidiellum* とオレゴン州の Snowshoe 層最上部試料中のそれを研究して次の結果を得た。前期ジュラ紀後期から後期ジュラ紀にかけて, この属には 18 種が認められる。そのうち *Eucyrtidiellum disparile*, *E. unumaense*, *E. pustulatum*, *E. semifactum*, *E. ptyctum* の 5 種が最も多い。これらの種は形態的にお互いに深い関連をもっていて, はじめに *E. disparile* から *E. unumaense* への変化にみられるような腹部の殻構造の変化, ついで, *E. unumasense* から *E. pustulatum*, *E. semifactum* を経て *E. ptyctum* にいたる変化にみられるような腹部の表面皺壁の発達という 2 段階からなる逐次変化過程を示す。Snowshoe 層の上部パソニアン統からは専ら *E. pustulatum* が見出されることから日本のジュラ紀層についての生層序学的対比を試みた。すなわち *Unuma echinatus* 群集帯は上部パソニアン統よりは下に, また *Dictyomitrella (?) kamoensis-Pantanellium foveatum* 群集帯の下部は上部パソニアン統に対比される。2 新種 *Eucyrtidiellum disparile* と *E. semifactum* を記載し, 関連種についても検討した。

永井ひろ美・水谷伸治郎

SHORT NOTES

24. DIMORPHISM AND GEOGRAPHIC DISTRIBUTION OF TWO PHENOTYPES OF A WEST ATLANTIC STALKED CRINOID *ENDOXOCRINUS PARRAE* (GERVAIS)*

TATSUO OJI

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Polymorphism in crinoids is thought to be rare, and while several examples of sexual dimorphism in stalkless crinoids have been reported (Clark, 1921, p. 369), no definite shape polymorphism has previously been described in stalked crinoids. The present paper describes dimorphism in the western Atlantic isocrinid *Endoxocrinus parrae* (Gervais). The geographic distribution and abundance of the two phenotypes are also discussed.

Endoxocrinus parrae (Gervais) (Figure 1A) is a common stalked crinoid in the tropical to subtropical western Atlantic; it has been collected many times in the Strait of Florida, the Bahamas and the West Indies, the Caribbean Sea off Cuba and the Yucatan Channel. The distribution also extends to San Luis, Brazil (Meyer *et al.*, 1978), and probably off Rio Grande, Brazil (Tommasi, 1969, as *Diplocrinus maclearanus*). This species lives at depths of 154 to 971 m, and it is most commonly collected between about 500 and 600 m (Meyer *et al.*, 1978).

Endoxocrinus parrae has a second morph, *Endoxocrinus prionodes*, previously described as a separate species by H.L. Clark (1941) (Figure. 1B). This species was distinguished from *E. parrae* by having projecting distal edges of the brachials, especially the proximal brachials of the finials. This fea-

ture gives the proximal finial arms a conspicuously serrate appearance. Meyer *et al.* (1978) suggested that *E. prionodes* is perhaps synonymous with *E. parrae*. Characteristics other than the proximal brachial morphology, such as stalk morphology, general size, number of arms, and kind and position of the ligamentary articulation, are similar in these two forms; however, the forms were thought to differ in some characteristics, such as the number of internodal plates and the number of arms.

Material.— A total 165 specimens, housed in the National Museum of Natural History (USNM), Smithsonian Institution, Washington, D.C. were examined. There were 115 specimens of normal *E. parrae*, 44 specimens of the serrate form ("*E. prionodes*"), and six intermediate specimens.

Two different species or intraspecific dimorphism?— For the sake of convenience, I abbreviate the typical form of *Endoxocrinus parrae* as PA and the form with the strongly serrate series of brachials PR. Most specimens of the two forms are usually clearly separated by the morphology of the brachials (smooth versus serrate), otherwise they cannot be separated (Figure 1). However, sometimes there are intergradations, and several specimens cannot be readily classified as either form. Moreover, recent collection records show that both types occur from the same stations. These lines of evidence seem

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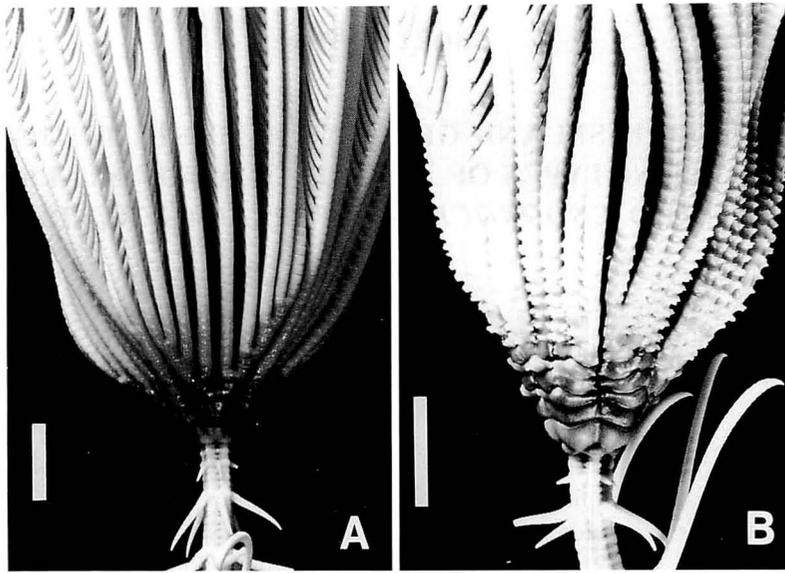


Figure 1. A: *Endoxocrinus parrae* (Gervais). No. E33406, U.S. National Museum. Collected at south of Rock Port, Great Abaco, Bahama Islands (25°59'30"N, 77°4'06"W, 287 m). B: "*Endoxocrinus prionodes* H.L. Clark", here referred to a phenotype of *E. parrae*. No. E32644, U.S. National Museum. Collected at west of Wood Cay, Great Abaco, Bahama Islands (26°4'48"N, 79°09'30"W, 624–618 m). Scale bars are 1 cm.

to support the conclusion that the two types are morphs of a single species, rather than two independent species.

Geographic cline.—I subdivide the main area of distribution, from the Lesser Antilles to the Yucatan Channel, into six subareas. These are, 1. off the Yucatan Peninsula, 2. around the western to central part of Cuba, 3. the Strait of Florida to the northern Bahamas, 4. the central Bahamas, 5. the eastern Bahamas to western Haiti, 6. eastern Haiti, Dominica to the Lesser Antilles.

Figure 2 shows the sample sizes of this species and the proportion of the two phenotypes (plus that of indeterminable type) in these six subareas. PR is generally abundant in the northern part of the range. In subarea 3, the northernmost subarea, PR comprises almost half the total. The proportion of PR in subarea 3 is significantly higher than that in subareas 3 to 6 ($G = 29.05$, $df = 1$, $p < .001$). There are no PR individuals in subarea 6. Furthermore, all seven specimens

collected off San Luis are PA. Therefore, PR is a phenotype which appears to exist in populations near the northern periphery of the species' distribution.

Bathymetric distribution.—PR seems to occur slightly deeper than PA (Figure 3). The null hypothesis that the bathymetric distributions of PR and PA are the same cannot be rejected ($G = 40.48$, $df = 3$, $p < .001$).

Discussion.—This is the first documentation of the presence of shape polymorphism in living stalked crinoids. The phenotype PR dominates in the northernmost distribution area and it lives significantly in rather deeper water than the phenotype PA. Such distribution pattern suggests that the PR is adapted to deeper habitat than the PA. Because the two phenotypes are often found from the same station, the two phenotypes probably form the same population in such places.

Many western Pacific isocrinids have a very wide distribution, yet there is no significant

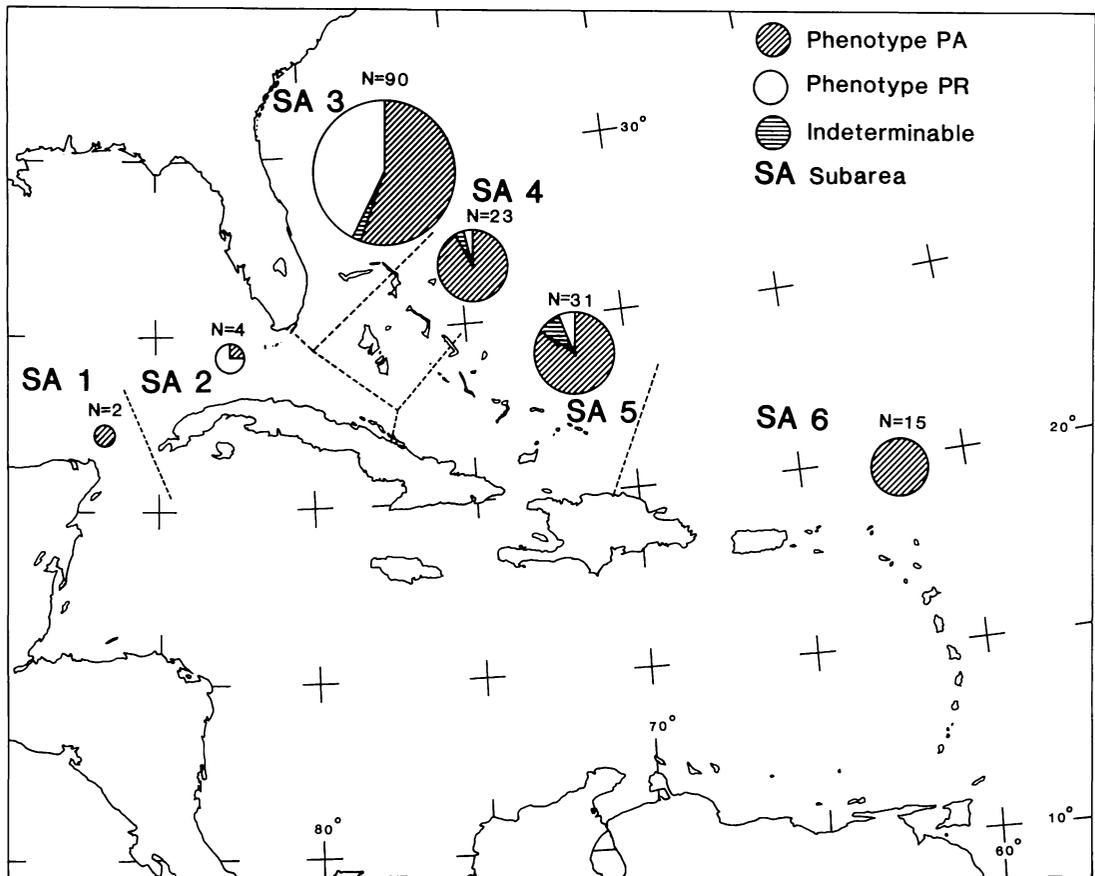


Figure 2. Distribution and proportion of the two phenotypes of *Endoxocrinus parrae* in the Caribbean region. The distribution is subdivided into six subareas. The proportion of the phenotype PR increases toward the north.

geographic variation in such species as *Endoxocrinus alternicirrus* and *Hypalocrinus naresianus* (Oji, 1989). While the present result appears superficially to contrast with such morphologic stability, it also suggests that there may be actually unrecognized polymorphisms in the Pacific isocrinids, especially in the much diversified and possibly oversplit species of *Metacrinus* and *Saracrinus*.

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thank David Pawson for allowing me to use USNM crinoid specimens for this study, and Cynthia Ahearn for her various help during my visit to the National Museum of Natural History. Thanks are also to David Meyer for the information of the stations of R/Vs Pilsbury and Gerda. Rich Mooi kindly sent me an important reference. Examined material includes many specimens collected recently by submersible dives made by the Harbor Branch Oceanographic Institution Inc. submersible programme. I thank John Miller for allowing me to study these well-preserved specimens. Contribution No. 18—Studies on bathyal echinoderms of the Bahama

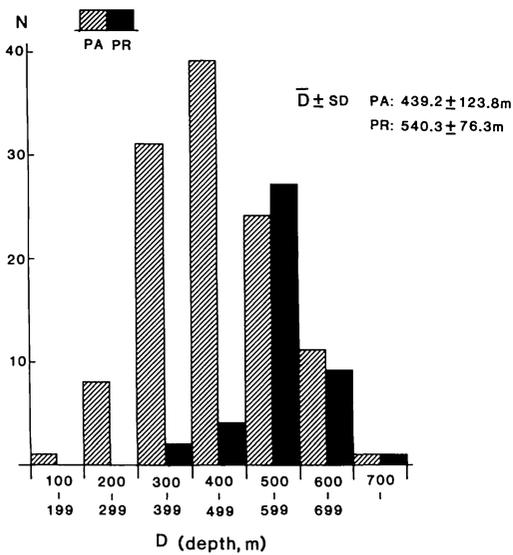


Figure 3. Bathymetric distribution of the two phenotypes of *Endoxocrinus parrae* from the Caribbean-West Indies area. Specimens with collection records of more than 100 m depth ranges are omitted.

Islands, J.E. Miller (Harbor Branch Oceanographic Institution), Principal Investigator.

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Appendix

Registered numbers of the specimens used in this study are listed below. The numbers are followed by parentheses indicating the number of individuals contained in the same lot under the same registered number. All the specimens are housed in the National Museum of Natural History, Smithsonian Institution (USNM).

Subarea 1: E18033(1) E18058(1).

Subarea 2: 12545(1), E17920(1), E21063(1), E21083(1).

Subarea 3: E17514(3), E17516(2), E17517(4), E17950(1), E17981(1), E17989(6), E17990(3), E17991(2), E17996(2), E18008(1), E18009(1), E18023(1), E18030(3), E18032(2), E18047(1), E18048(1), E18050(2), E21004(1), E21005(2), E21012(1), E21020(9), E21024(1), E21037(5), E21052(1), E21071(1), E21072(2), E21084(1), E25908(3), E26002(13), E32644(2), E32655(1), E32656(1).

Subarea 4: E32636(1), E32637(1), E32638(1), E32640(4), E32641(1), E32642(1), E32643(1), E32653(1), E32657(2), E32660(1), E32661(1), E32664(3), E32666(1), E33403(2), E33406(2).

Subarea 5: E18035(23), E32639(1), E32654(1), E32658(1), E32659(1), E32662(1), E32663(1), E33404(1), E33405(1).

Subarea 6: E17994(2), E18020(2), E19967(1), E19968(1), E19969(1), E21018(4), E21022(1), E21076(2), E26001(1).

PROCEEDINGS OF THE PALAEOLOGICAL
SOCIETY OF JAPAN

日本古生物学会 第 139 回例会

日本古生物学会第 139 回例会が 1990 年 6 月 30 日・7 月 1 日に瑞浪市化石博物館で開催された (参加者 163 名)。

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軟体動物特に腹足類の起源と系統発生に関する 2・3 の話題……………小澤智生
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……………小浜耕治
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……………富田 進・尾ヶ井清彦
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……………松居誠一郎・磯 政道
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中新世アフリカ哺乳動物群にみられる古環境事件
……………仲谷英夫・渡部真人

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美濃帯ヘルム紀新世層状チャートにおける *Albaillel-
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Unuma echinatus 群集 (ジュラ紀中世放散虫) の群集
組成 [その4] 八尾 昭

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535	8 (Abstract)	<i>inokoshiensis</i>	<i>inokosiensis</i>

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- ◎1991年年会・総会は1月31日～2月2日に東北大学理学部で開催されます。講演申込は12月10日(必着)締切です。今回より講演の申し込み方法が変更されましたのでご注意ください。詳しくは化石48号をご覧ください。
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