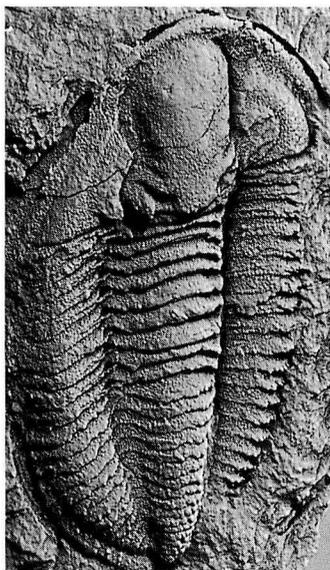


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The fossil on the cover is *Phillipsia ohmorensis* Okubo, an Early Carboniferous trilobite from the Hikoroichi Formation in the Higuchizawa valley, Ofunato City, Iwate Prefecture, northeast Japan (Collected by A. Haga, PA 5766,  $\times 3.0$ ; after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

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### **PALAEONTOLOGICAL SOCIETY OF JAPAN**

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**907. A NEW SPECIES OF *VEPRICARDIUM* (BIVALVIA ;  
MOLLUSCA) FROM THE MIOCENE KATSUTA GROUP IN  
OKAYAMA PREFECTURE, SOUTHWEST JAPAN\***

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**Abstract.** An interesting new cardiid belonging to the genus *Vepricardium* was discovered from a mudstone of the Middle Miocene Yoshino Formation of the Katsuta Group in Okayama Prefecture, southwest Japan. This species, *Vepricardium (Vepricardium) okamotoi*, sp. nov., is described herein, and its average relative growth is examined. Judging from the mode of occurrence, lithofacies and associated forms, this species must have lived in a muddy bottom in the inner sublittoral zone, and is regarded as an indicator of a tropical marine environment at that time.

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**Key words.** *Vepricardium*, Cardiidae, Katsuta Group, Miocene, Southwest Japan.

### Introduction

A large number of molluscan specimens were collected from the Yoshino Formation of the Katsuta Group (Kawai, 1957) at Niida, Tsuyama City, Okayama Prefecture by T. Osafune and A. Obayashi. Based on some of these molluscs, I have already reported *Perna oyamai*, *Tellinella osafunei* and *Nipponarca japonica* as new to science (Taguchi, 1983a, b). On the other hand, a geological investigation around the fossil locality has been made by me during the past five years.

In this paper, an interesting new cardiid shell is described together with the discussion on its average relative growth and paleoecological characteristics.

### Fossil locality and geologic setting

A new cardiid species occurs in a mudstone of the Yoshino Formation at Niida, Tsuyama City, Okayama Prefecture. This site (Lat. 35°3'5"N, Long. 134°4'1"E) is designated as

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the type locality (Figure 1). The Yoshino Formation around this locality disconformably overlies the Uetsuki Formation and is composed of basal conglomerate, tuff and mudstone with intercalations of lignite in ascending order. The molluscan fossils including a new cardiid are collected from the uppermost part of the Yoshino Formation as shown in Figure 2.

### Description of new species of *Vepricardium*

Family Cardiidae Lamarck, 1809  
Subfamily Cardiinae Lamarck, 1809  
Genus *Vepricardium* Iredale, 1929  
Subgenus *Vepricardium* (s.s.) Iredale, 1929  
*Vepricardium (Vepricardium) okamotoi*  
Taguchi, sp. nov.

Figures 6-1a-10b, 7

**Material.**—Twenty-three specimens are examined. Among them, 10 specimens are selected as the type. Holotype: MFM20015, Paratypes: MFM20016, MFM20017, MFM20022, MFM20025, MFM20027, MFM20031,

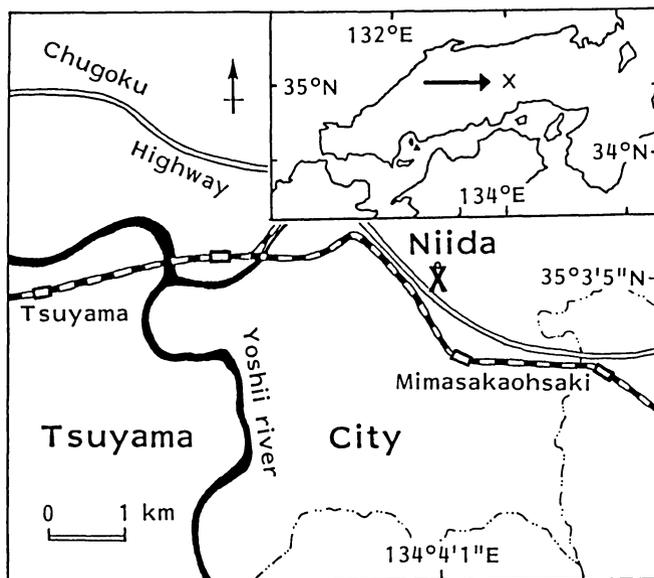


Figure 1. Fossil locality (X).

MFM20033, MFM20034, MFM20037.

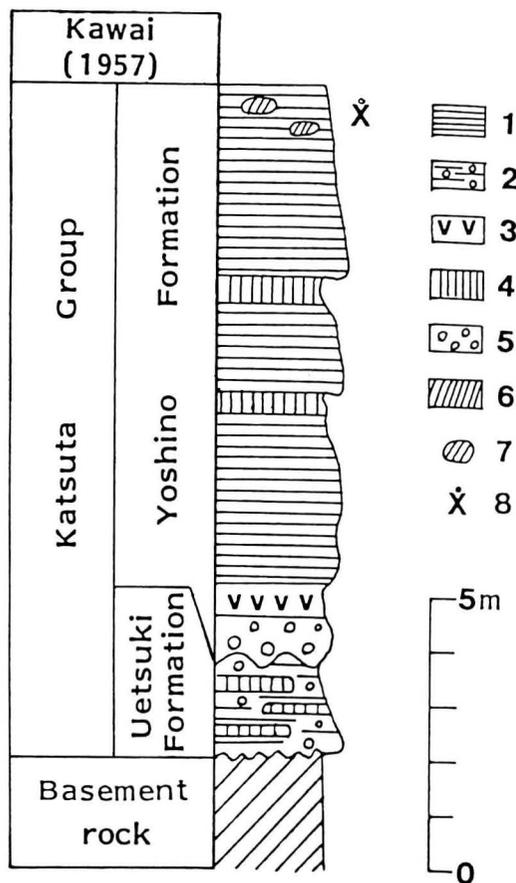
*Diagnosis.*—Radial ribs numerous, adorned with many prickles. Dentition composed of moderate cardinal and lateral teeth.

*Description.*—Shell moderate in size, moderately thick, fairly inflated, subquadrate in shape; equivalve, inequilateral, slightly longer than height. Antero-dorsal margin short, obliquely straight, connected well-rounded anterior margin. Postero-dorsal margin longer than antero-dorsal one, nearly straight, passing into subquadrate or arched posterior margin. Ventral margin broadly rounded. External surface of shell sculptured by concentrics and radials. Concentric lines smooth in main part but imbricated in anterior and posterior parts. Radial ribs 44 to 52 in number, averaging about 47, provided with many prickles on posterior ribs, round-topped in anterior and posterior parts but flat-topped in the main part. Interstices of radial ribs shallow, angular in cross section, wider than ribs in anterior and posterior parts while narrower in main part. Beaks low, pointed, prosogyrate, situated near the middle of the shell or a little anteriorly. Umbo more or less swollen. Lunule cordate and

smooth; escutcheon smooth, pointed at postero-dorsal corner. Dentition composed of cardinals and laterals; anterior cardinal tooth obliquely straight; posterior one short, vertical; laterals located at the same distance from beaks; anterior tooth large, trigonal; posterior one long, linear, curved. Hinge plate stout, broadly arched. Inner margin seems to be crenulated. Muscle scar and pallial line unknown.

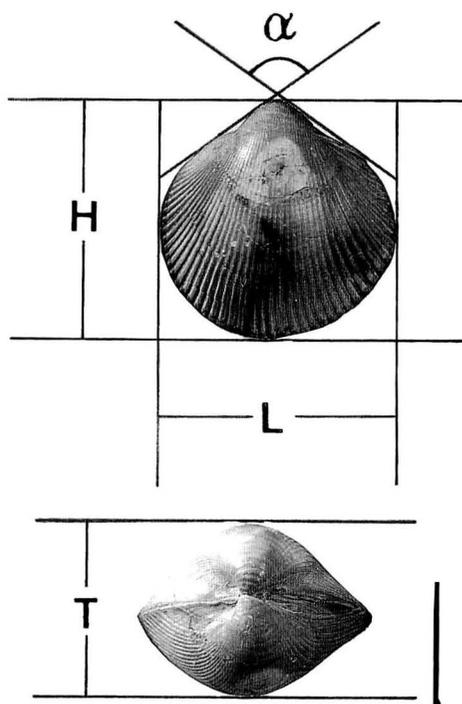
*Repository.*—The specimens described are all kept in the collection of Mizunami Fossil Museum with prefix of MFM.

*Comparison.*—This new species is closely related to *Regozara fraseri* Garrard (1963), a recent cardiid from Queensland, Australia in its general feature, but is distinguished therefrom by its larger number of radial ribs and less numbered prickly ribs. This species is also allied to the recent *Vepricardium pulchricostatum* Iredale (1929) described from Sydney, Australia in its outline, but differs from the latter in its quadrate, smaller and lower shell with a larger number of radial ribs, which have prickles only in the posterior part. Of fossil species, *Vepricardium kyushuense* originally reported from the Miyaza-



**Figure 2.** Geologic column at Niida, Tsuyama City. 1: Mudstone, 2: Pebble bearing sandy mudstone, 3: Tuff, 4: Lignite, 5: Pebbly conglomerate, 6: Basement rock, 7: Nodule, 8: Fossils.

ki Group by Shuto (1960) most resembles this species in shell size and the shape of ribs. The former, however, is distinguishable from the latter by its more round shell with a large and touching umbo and a smaller number of radial ribs possessing prickles in both the anterior and posterior parts. Otuka (1938) described a cardiid from the Bihoku Group in Shobara City, Hiroshima Prefecture as *Cardium (Bucardium) ogurai*. In comparison with this new species, *C. (B.) ogurai* has the more swollen shell with no prickles on the radial ribs and a smaller number of ribs *i.e.* 36–40 in number.



**Figure 3.** Basic morphology for measurements. L: Shell length, H: Shell height, T: Shell thickness,  $\alpha$ : Angle of antero-dorsal and postero-dorsal margins.

The specific name of this new species is dedicated to Kazuo Okamoto of Hiroshima University.

**Biometry.**—For the purpose of clarifying the growth pattern of this new species, a biometrical analysis is made after the methods of Hayami (1969) and Noda (1986). The basic morphology for measurements is shown in Figure 3. The morphologies of shell are measured and the ratio of shell length to shell height (L/H) and of shell thickness to shell height (T/H) are calculated as shown in Table 1. Biometric characters such as mean value, standard deviation and Pearson's coefficient variation concerning number of radial ribs,  $\alpha$ , L/H and T/H are also calculated. These data are shown in Table 2. Table 3 shows data of the average relative growth of this new species. Based on Table 3, the reduce major axis is demonstrated in Figures 4 and 5. Considering the correlation

**Table 1.** Measurements of *Vepricardium* (s.s.) *okamotoi*, sp. nov.

Registered No.	Valve	Length (mm)	Height (mm)	Thickness (mm)	No. of ribs	$\alpha^\circ$	L/H	T/H
MFM20015	Right	30.3	29.9	21.3	47	120	1.01	0.71
MFM20016	Left	21.1	20.8	15.3	50	117	1.01	0.74
MFM20017	Left	25.4	24.0	17.7	48	119	1.06	0.74
MFM20018	Right	24.5	22.4	16.7	45	119	1.09	0.75
MFM20019	Right	19.0	18.1	13.1	47	120	1.05	0.72
MFM20020	Left	21.0	20.8	14.4	51	116	1.00	0.69
MFM20021	Right	23.3	22.6	15.8	47	115	1.03	0.70
MFM20022	Left	15.9	15.7	11.9	48	115	1.01	0.76
MFM20023	Right	24.7	24.4	17.0	47	114	1.01	0.70
MFM20024	Right	29.2	28.1	20.9	46	117	1.04	0.74
MFM20025	Right	26.5	25.1	17.7	45	118	1.06	0.71
MFM20026	Right	19.7	18.8	13.3	45	122	1.05	0.71
MFM20027	Right	14.6	13.1	9.6	48	126	1.11	0.73
MFM20028	Right	26.4	26.3	19.0	44	125	1.00	0.72
MFM20029	Right	17.0	16.8	12.1	45	117	1.01	0.72
MFM20030	Right	23.6	23.3	16.5	44	117	1.01	0.71
MFM20031	Right	29.9	28.4	21.0	47	124	1.05	0.74
MFM20032	Left	25.3	23.8	17.9	45	116	1.06	0.75
MFM20033	Left	32.2	28.8	21.4	52	124	1.12	0.74
MFM20034	Left	35.0	34.8	24.7	46	119	1.01	0.71
MFM20035	Right	26.5	25.2	18.0	48	126	1.05	0.71
MFM20036	Left	26.7	25.4	18.5	46	116	1.05	0.73

$\alpha$  ; Angle of antero-dorsal and postero-dorsal margins, L/H ; Ratio of shell length to shell height, T/H ; Ratio of shell thickness to shell height.

**Table 2.** Biometric characters of *Vepricardium* (s.s.) *okamotoi*, sp. nov.

	Number of radial ribs	$\alpha$	L/H	T/H
N	22	22	22	22
m	46.8	119.2	1.040	0.724
s	2.075	3.664	0.034	0.019
v	4.434	3.074	3.269	2.624

N ; Sample size, m ; Mean value, s ; standard deviation, v ; Pearson's coefficient variation.

**Table 3.** Data showing the average relative growth of *Vepricardium* (s.s.) *okamotoi*, sp. nov.

	$\alpha$	$\beta$	$\bar{L}'$	$\bar{H}'$	$\bar{T}'$	r	N
L and H	0.995	1.057	1.3779	1.3603		0.9894	22
T and H	0.998	0.730		1.3603	1.2199	0.9908	22

$\alpha$  ; Growth ratio,  $\beta$  ; Initial growth index,  $\bar{L}'$  ; Mean of  $L'$  ( $L' = \log L$ ),  $\bar{H}'$  ; Mean of  $H'$  ( $H' = \log H$ ),  $\bar{T}'$  ; Mean of  $T'$  ( $T' = \log T$ ), r ; Correlation coefficient, N ; Sample size.

coefficient and the sample size, the null hypothesis of "isometry" cannot be rejected judging from the table and figure of Hayami and Matsukuma (1971). That is to say, the relations of shell length versus shell height and of shell thickness versus shell height

represent to be "isometry", respectively.

*Remarks on paleoecology.*—A lot of molluscan specimens including *Vepricardium* (*Vepricardium*) *okamotoi*, sp. nov. are obtained from a mudstone of the Yoshino Formation at Niida, Tsuyama City. The identified species composed of 19 pelecypod

species and 37 gastropod species are listed in Table 4. All pelecypods except *Ostrea* sp. nov. occur with conjoined valves, and gastropods suffer little injury and wear. This mode of occurrence indicates that the fauna is autochthonous. This assemblage, which has been named *Tellinella-Perna-Vepricardium-Vicaryella* (Ohe *et al.*, 1986), represents a

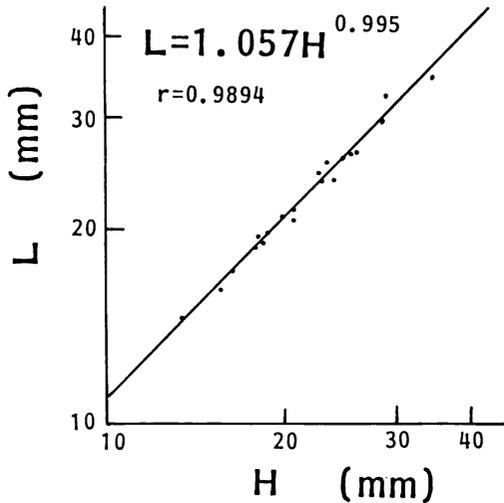


Figure 4. Relationship between shell length (L) and shell height (H) in *Vepricardium* (s.s.) *okamotoi*, sp. nov.

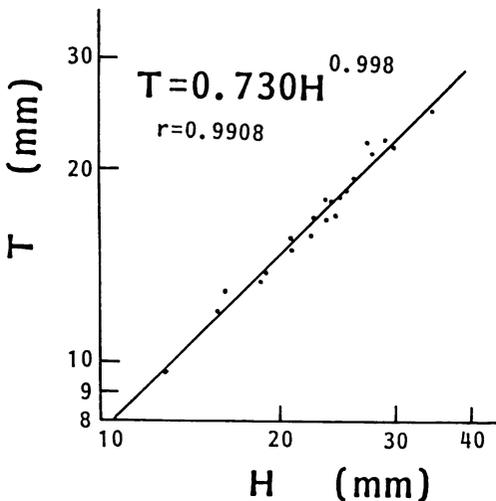


Figure 5. Relationship between shell thickness (T) and shell height (H) in *Vepricardium* (s.s.) *okamotoi*, sp. nov.

Table 4. Fossil molluscs collected from a mudstone of the Yoshino Formation of the Katsuta Group at Niida, Tsuyama City.

Specific name	Number of individuals
<i>Nipponarca japonica</i> Taguchi	13
<i>Scapharca abdita</i> (Makiyama)	4
<i>Perna oyamai</i> Taguchi	1110
<i>Anomia</i> sp.	1
<i>Ostrea</i> sp. nov.	96
<i>Modiolus</i> ( <i>Modiolusia</i> ) sp.	2
<i>Cycladicama cumingii kukiugaensis</i> Hayasaka	4
<i>Eucrassatella</i> ? sp.	1
<i>Vepricardium</i> (s.s.) <i>okamotoi</i> , sp. nov.	570
<i>Cardilia toyamaensis</i> Tsuda	2
<i>Tellinella osafunei</i> Taguchi	1556
<i>Gari</i> sp.	1
<i>Psammobia</i> sp. nov.	73
<i>Pharella</i> sp.	1
<i>Trapezium cheonbugensis</i> Yoon	1
<i>T. modiolaeforma</i> Oyama et Saka	1
<i>Paphia euglypta ohiroii</i> Masuda	3
<i>Mactra</i> sp.	1
<i>Clementia japonica</i> Masuda	4
<i>Calliostoma</i> ( <i>Tristichotrochus</i> ) <i>myonchonenensis</i> Hatai et Kotaka	19
<i>Tristichotrochus</i> sp.	1
<i>Cantharidus mizunamiensis</i> Itoigawa et Shibata	1
<i>Chlorostoma</i> sp.	1
<i>Teinostoma yabei</i> Masuda	1
<i>Turbo</i> ( <i>Marmorostoma</i> ) <i>minoensis</i> Itoigawa	1
<i>Lunella</i> sp.	35
<i>Neritina</i> sp.	1
<i>Littorinopsis miodelicatula</i> Oyama	1
<i>L.</i> sp.	1
<i>Turritella</i> (s.s.) <i>kiiensis</i> Yokoyama	7
<i>T.</i> sp.	3
<i>Vicaryella bacula</i> (Yokoyama)	4
<i>V. ishiiana</i> (Yokoyama)	387
<i>V. notoensis</i> Masuda	22
<i>Terebralia</i> sp. nov.	24
<i>Baillaria toshioi</i> Masuda	1
<i>B.</i> sp. nov.	3
<i>Tateiwaia tateiwa</i> (Makiyama)	1
<i>T. yamanarii</i> (Makiyama)	5
<i>T.</i> sp.	7
<i>Bittium</i> sp.	6
<i>Proclava</i> sp.	5
<i>Calyptraea tubura</i> Otuka	2
<i>Erosaria</i> sp.	1
<i>Euspira meisensis</i> (Makiyama)	48
<i>Pygmaeorota</i> sp.	1
<i>Echinophoria</i> ( <i>Shichiheia</i> ) sp.	1
<i>Bedevina</i> sp.	1
<i>Boreotrophon</i> sp.	1
<i>Nebularia</i> sp.	2
<i>Siphonalia</i> sp. nov.	19
<i>Chrysame</i> sp.	2
<i>Paradrillia</i> sp.	2
<i>Nipponaphera</i> sp. nov.	14
<i>Pugilina</i> ( <i>Hemifusus</i> ) <i>sazanami</i> (Kanehara)	29
<i>Reticunassa simizui</i> (Otuka)	1
<i>Zeuxis minoensis</i> Itoigawa	294
Total of individuals	4399



1a



2a



3a



1b



2b



3b



5a



5b



4a



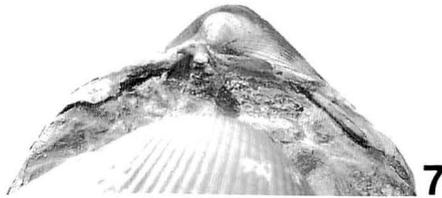
6a



4b



6b



7



8a



9a



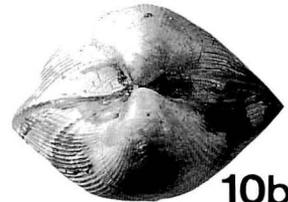
10a



8b



9b



10b

muddy bottom fauna in the inner sublittoral zone judging from the mode of occurrence, lithofacies and faunal constituents mentioned above.

*Vepricardium* (*Vepricardium*) *okamotoi* also occurs in mudstones of the Yoshino Formation at Mino and at Tanaka both in Shoo-cho. Therefore, it is considered that this new species had adapted to muddy substratum. On the contrary, "*Vasticardium*" *ogurai* (Otuka), a representative and widespread Miocene cardiid of Japan, seems to be adapted to a sandy bottom (Otuka, 1938, Shuto, 1960, Masuda, 1966, Itoigawa and Nishikawa, 1976, Itoigawa *et al.*, 1981, Nakagawa and Takeyama, 1985, Okamoto *et al.*, 1986, Ueda, 1986 etc.).

In the Miocene of Japan, tropical molluscs are not well-known, hence it is noticeable

that some tropical genera are included in Japanese Middle Miocene molluscan fauna (Otuka, 1938, Oyama, 1950, Tsuda, 1959, Itoigawa, 1960, Itoigawa *et al.*, 1981, Matsuo-ka, 1979, Taguchi, 1981, 1983a). They are as follows; *Isognomon* (s.s.), *Batissa*, *Geloina*, *Perna*, *Placuna*, *Maoricardium*, *Katelysia*, *Novaculina*, *Apolymetis*, *Phyloda*, *Melanoides*, *Telescopium*, *Terebralia*, *Chicoreus* (*Rhizophorimurex*), *Labiostrombus*, *Globularia*, *Rimella*, *Volema* and *Pionoconus*. The living species of the genus *Vepricardium* such as *V. multispinosum*, *V. sinense* and *V. asiaticum* are distributed in the lower latitude area as Taiwan (Formosa) to north Australia (Habe, 1977). Accordingly, *Vepricardium* (*Vepricardium*) *okamotoi*, sp. nov. probably indicates tropical marine condition in the Middle Miocene of Japan ranging from 16 to

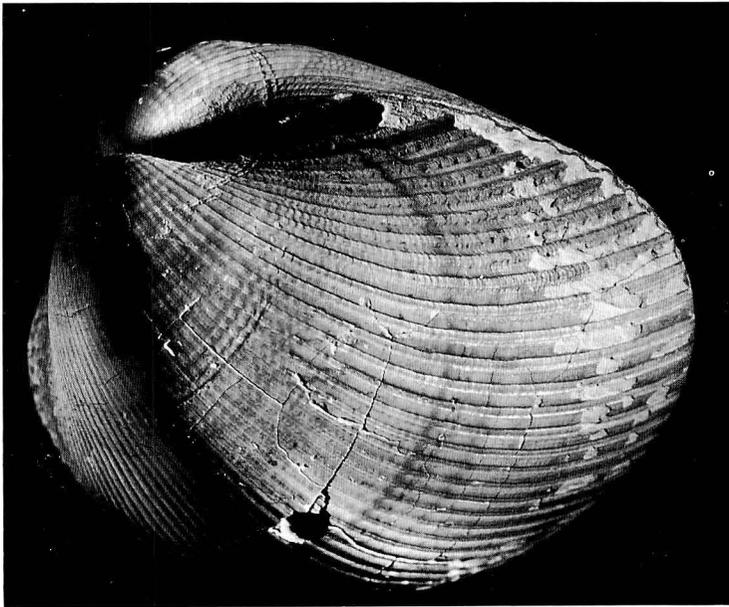


Figure 7. Prickers on posterial ribs of *Vepricardium* (s.s.) *okamotoi*, sp. nov. (MFM20033)  $\times 3$ .

← Figure 6-1a–10b. *Vepricardium* (*Vepricardium*) *okamotoi*, sp. nov. 1a–b, lateral and apical views, holotype MFM20015; 2a–b, lateral and apical views, paratype MFM20025; 3a–b, lateral and apical views, paratype MFM20031; 4a–b, lateral and apical views, paratype MFM20016; 5a–b, lateral and apical views, paratype MFM20027; 6a–b, lateral and apical views, paratype MFM20022; 7, internal view of hinge area, paratype MFM20037,  $\times 2$ ; 8a–b, lateral and apical views, paratype MFM 20033; 9a–b, lateral and apical views, paratype MFM 20017; 10a–10b, lateral and apical views, paratype MFM20034. All figures in natural size, unless other wise stated.

15 Ma.

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Mino 美野, Niida 新田, Okayama 岡山, Tanaka 田中, Takakura 高倉, Tsuyama 津山, Toyokuda 豊久田, Shoo-cho 勝央町, Yoshino 吉野.

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西南日本岡山県の中新統勝田層群からの *Vepricardium* の一新種: 西南日本の岡山県勝田層群吉野層 (中期中新統) の泥岩から, *Vepricardium* に所属する興味深いザルガイが発見された。新種, *Vepricardium (Vepricardium) okamotoi* として記載し, その平均相対成長を検討した。この種は, 産状, 岩相および随伴種から判断すると, 上部浅海帯の泥底に生息しており, 当時の熱帯環境を指示する一指標とみなされる。 田口栄次

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**908. AN INTERESTING PACHYDISCID AMMONITE FROM  
HOKKAIDO, WITH REMARKS ON RELEVANT TAXA\***  
(STUDIES OF CRETACEOUS AMMONITES FROM HOKKAIDO—LXVII)

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**Abstract.** A peculiar ammonite recently acquired by Masatoshi Kera from the Coniacian rock of the Masago-zawa in the Yubari Mountains, central Hokkaido, is described as a new species. It may represent the earliest species of *Eupachydiscus* Spath, 1922, retaining some features which characterize certain species of *Tongoboryceras* Houša, 1967. In this connexion *Tongoboryceras* is redefined so that it may include comprehensively more species. Also *Menabonites* Houša, 1967 is reviewed with a proposal to include it in *Pseudojacobites* Spath, 1922 in a revised sense. In the available material there is no significant difference of size, i.e. a microconch versus macroconch relationship, between bi- or trituberculate species of *Pseudojacobites* and 'normal' pachydiscid species of *Tongoboryceras*, although the two genera are closely allied to each other.

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**Key words.** *Lewesiceras*, *Tongoboryceras*, *Menabonites*, *Pseudojacobites*, *Eupachydiscus*, Coniacian.

### Introduction

Masatoshi Kera, a friend of mine in Hokkaido, informed me that he acquired in October 1988 an ammonite which is unfamiliar to him from a locality in the Yubari Mountains of central Hokkaido. It was sent to me for a palaeontological study. In this paper I describe it as a new species of *Eupachydiscus*. It shows, however, peculiar characters and is older than typical species of the genus in the Santonian and Lower Campanian of Japan.

In connexion with this identification, I reexamine some of the Turonian and Coniacian species which were described under *Lewesiceras*, *Tongoboryceras*, *Menabonites*, and *Pseudojacobites*, giving remarks on these genera.

### Notes on some genera of the family Pachydiscidae Spath, 1922

I thought that the taxonomy at generic level of this family was satisfactory. When I described some species from the Turonian and Coniacian of Hokkaido (Matsumoto, 1979), I was sorry to have made no mention of the two genera established by Houša (1967). In this paper I should give my remarks on them.

#### Genus *Tongoboryceras* Houša, 1967

*Type species.*—*Lewesiceras tongoboryense* Collignon, 1952 (see Collignon, 1955, p. 25, pl. 2, fig. 3; also 1965, p. 33, pl. 428, fig. 1772) by original designation (Houša, 1967, p. 41).

*Remarks.*—This genus has been acknowledged by Wright (1979, p. 316) and Kennedy (1984, p. 34). Beside the type species from the Coniacian of Madagascar, *T. rhodanicum* (Roman et Mazeran) (1913, p. 18, pl. 1, fig. 10

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under *Pachydiscus*) (Wright, 1979, p. 316, pl. 6, fig. 1), from the Upper Turonian of France and England, is a well known species of this genus.

The species called *Lewesiceras satoi* Matsumoto (1979, p. 34, text-fig. 3, pl. 5, fig. 1), from the Turonian of Hokkaido, is now regarded as an example of *Tongoboryceras*, because it is fundamentally similar to *T. rhodanicum*. The former has less depressed whorls, more numerous and finer ribs and stronger umbilical tubercles as compared with the latter, but the difference is by no means great, being that of allied but separate species of the same genus.

*Lewesiceras kawashitai* Matsumoto (1979, p. 32, text-fig. 2; pl. 4, fig. 1), from the Coniacian of Hokkaido, should also be transferred to this genus, because its suture is quite similar to that of *T. rhodanicum* and *T. satoi*, being more complex than that of *Lewesiceras*. It represents a subgroup of *Tongoboryceras* which has much depressed whorls with rather coronate or reniform section, narrow but raised ribs and fairly strong tubercles. Some one may require a subgeneric separation for this subgroup, but the type species (*T. tongoboryense*) itself has considerably depressed whorls. *Lewesiceras elmii* Collignon (1965, p. 36, pl. 429, figs. 1777-1779), from the Coniacian of Madagascar, shows an intermediate value of B/H between *T. tongoboryense*

and *T. kawashitai* (Table 1), being much greater than that of typical species of *Lewesiceras*. It is probably referred to *Tongoboryceras*, although Collignon did not describe precisely its suture.

In the generic diagnosis of *Tongoboryceras*, Houša took account of the weakness of umbilical tubercles. Such a character may be observable in some particular species, but some other species of this genus have tubercles of moderate intensity (e.g. *T. rhodanicum* in late growth-stage and *T. satoi*) and still others have prominent tubercles (e.g. *T. elmii* and *T. kawashitai*). Generally the ribs and tubercles may look weak, if an internal mould alone is dealt with.

On the ground of above observations, I should properly redefine *Tongoboryceras* as follows:

*Generic diagnosis of Tongoboryceras.*—Shell of moderate size, so far as known; involution moderate; umbilicus of moderate width to fairly narrow. Whorls more or less broader than high, with B/H a little more than 1.0 to somewhat below 2.0, subrounded to reniform in section.

Ribs of unequal length and strength. Major ribs with tubercles of various intensity at or outside the subrounded umbilical edge, disposed at fairly wide intervals and some of them accompanied with a periodic constriction. One to several minor ribs of unequal

**Table 1.** Measurements (in mm) of selected species of *Tongoboryceras*.

Species	Specimen	D	U	H	B	B/H	H/h	MR : VR
<i>T. tongoboryense</i> ,	HT*	59 (1)	18 (.31)	27 (.46)	38 (.64)	1.41	1.13	6.5 : 17 + $\alpha$
<i>T. rhodanicum</i> ,	HT**	75 (1)	~19 (.25)	33 (.44)	~46 (.60)	1.39	1.43	4 : 19
<i>T. rhodanicum</i> ,	Wr.**	94 (1)	~29 (.30)	38 (.40)	~49 (.52)	1.29	1.41	5 : 19
<i>T. satoi</i> ,	HT	124 (1)	40 (.32)	52 (.42)	~61 (.48)	1.17	1.62	5 : 20
<i>T. satoi</i> ,	HT (-180°)	—	—	35	44.5	1.27	—	5 : 21
<i>T. kawashitai</i> ,	HT	87 (1)	30 (.34)	32 (.37)	58 (.67)	1.81	1.28	7 : 22
<i>T. elmii</i> ,	HT*	67 (1)	20 (.30)	28 (.42)	48 (.73)	1.75	1.47	6 : 18

D = diameter, U = width of umbilicus, H = whorl-height, B = whorl-breadth, h = whorl-height 180° prior to H, MR : VR = number of major ribs : that of ventral ribs in a half whorl; HT = holotype; Wr. = Wright, 1979, pl. 6 fig. 1; \* cited from original papers (Collignon, 1955, 1965); \*\* measured on photos; no mark = measured on actual specimens by myself.

length intercalated on each interspace of the major ribs; some of them may branch from the latter. Ribs nearly straight or gently concave or somewhat flexuous on the flank, with more or less forward curve at the ventrolateral shoulder, crossing the venter with gentle or moderate convexity.

Sutures of the pachydiscid pattern, with trifold L and U2, bifid lateral saddles (E/L, L/U2 and inside U2), and abruptly descending auxiliaries. In late growth-stages the elements are fairly deeply and finely incised; the stems of lateral saddles much narrowed and those of L and U2 deeper than broad and moderately (but not much) narrowed.

In general the sutures of *Tongoboryceras* (e.g. Collignon, 1955, pl. 2, fig. 3 for *T. tongoboryense*; Wright, 1979, pl. 6, fig. 1 for *T. rhodanicum*; Matsumoto, 1979, text-figs. 2, 3 for *T. kawashitai* and *T. satoi*) are more complex with narrower elements than those of typical *Lewesiceras* (e.g. Wright and Kennedy, 1981, text-fig. 12 for *L. peramplus*; Matsumoto, 1979, fig. 1 for *L. mantelli* [=

'*sharpei*']), but less complex and have less narrowed stems of elements than those of *Anapachydiscus* (e.g. Yabe and Shimizu, 1921, pl. 9, fig. 2 and pl. 8, fig. 2 for *A. fascicostatus*) and *Pachydiscus* in the correct sense (e.g. Grossouvre, 1894, fig. 80 for *P. neubergicus*).

Genera *Pseudojacobites* Spath, 1922  
and *Menabonites* Houša, 1967

*Type species of Pseudojacobites.*—*Pachydiscus farmeryi* Crick, 1910 by original designation (Spath, 1922, p. 121).

*Type species of Menabonites.*—*Pachydiscus anapadensis* Kossmat, 1898 by original designation (Houša, 1967, p. 41).

*Remarks.*—*Ps. farmeryi* (Crick) (1910, p. 345, pl. 27, figs. 1, 2), from the Upper Turonian Chalk Rock of England, has been amply redescribed by Wright (1979, p. 313, fig. 2; pl. 4, fig. 5; pl. 5, fig. 1; pl. 6, figs. 2, 3), who regarded *Pseudopuzosia marlowensis* (Noble, 1911) (p. 398, text-figs. 1, 2) as its

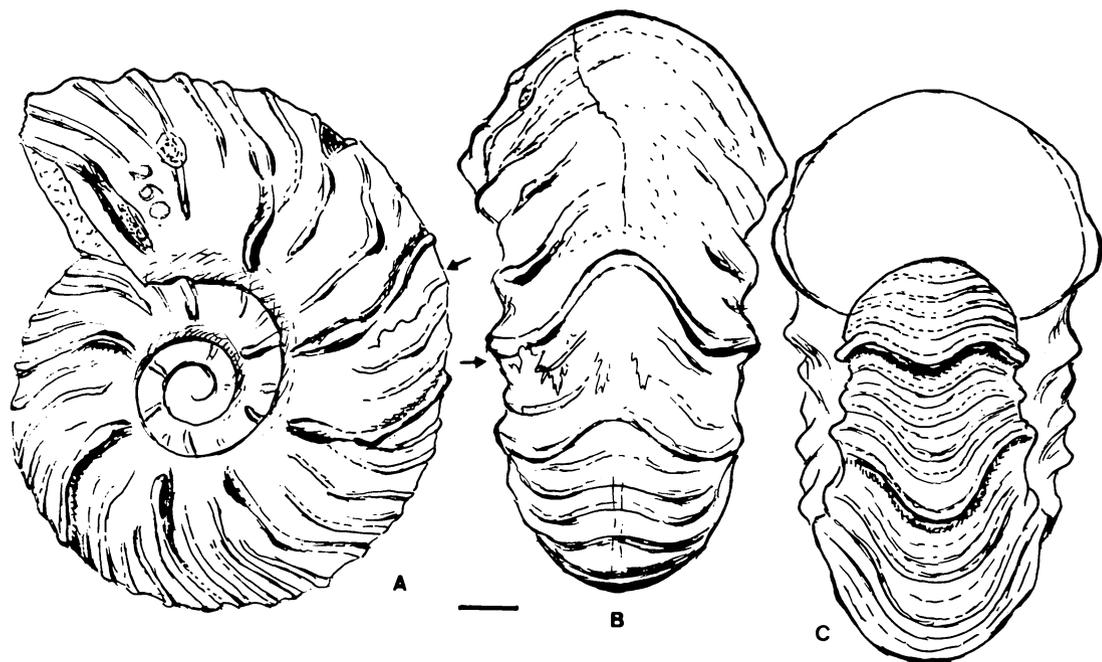
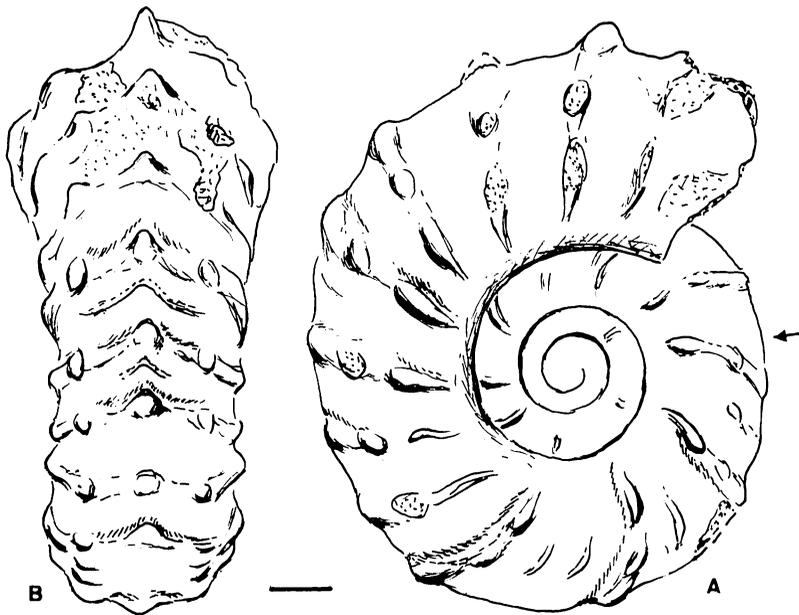


Figure 1. *Pseudojacobites anapadensis* (Kossmat). Lateral (A), rear (B) and frontal (C) views of the lectotype, GSI. 260. Arrow: last suture. Bar: 10 mm. (T.M. delin.)



**Figure 2.** *Pseudojacobites rosalinus* (Stoliczka). Lateral (A) and rear (B) views of the holotype, GSI. 154. Bar: 10 mm. (T.M. delin.)

synonym. I once investigated the holotypes and other examples of the two nominal species and thought that *Pseudopuzosia* may be a smoothing offshoot from *Lewesiceras* (see Matsumoto, 1979, p. 37, 42). Incidentally, *Pseudopuzosia* sp. reported by Birkelund (1973, p. 141, fig. 10; pl. 12, fig. 1) from Sardal on the west coast of Sweden is, in my present opinion, *Lewesiceras* sp., because of its broad and minutely indented lobes and saddles of the suture, less depressed whorl and distinct tubercles and ribs in the preserved middle-aged part. It is not an example of *Pseudojacobites* in a revised sense. Wright (1979 p. 312) has already referred it to *L. woodsi* Wright.

Also I examined in the Geological Survey of India (Calcutta) the two syntypes of *Pachydiscus anapadensis* Kossmat (1898, p. 90) (= *Ammonite peramplus* Mantell of Stoliczka, 1865, p. 130, pl. 65, figs. 1, 2), from the Trichinopoly Group of India, of which the larger one, GSI 260 (Fig. 1 of this paper) is here designated as the lectotype. In comparison with them, I examined also the holotype,

GSI 154, of *Ammonites rosalinus* Stoliczka (1864, p. 65, pl. 34, fig. 2) (Kossmat, 1898, p. 91, pl. 14, fig. 3 under *Pachydiscus*) (Fig. 2 of this paper). The latter species was the type species of *Rotalinites* Shimizu, 1935, which should be a synonym of *Pseudojacobites* (see Wright and Matsumoto, 1954, p. 124).

The lectotype of *P. anapadensis* looks fairly well preserved but is incomplete in showing only an earlier part (about 90°) of the body chamber. In addition to the weak and small (*i.e.* incipient) ventrolateral bulges in the septate part of the outer whorl, more distinct ventrolateral nodes appear on the early part of the body chamber. The venter of this part of the body chamber is not evenly rounded but has a blunt summit (contrary to Stoliczka's too much broadened illustration) and the ribs are markedly projected on the venter as those of *P. rosalinus*. These features suggest that the mid-ventral tubercles may appear in the late part of the adult body chamber.

In fact, *Lewesiceras masiaposense* Collignon, 1952, (see 1955, p. 21, pl. 1, fig. 1),

**Table 2.** Measurements (in mm) of selected species of *Pseudojacobites*.

Species	Specimen	D	U	H	B	B/H	H/h	MR:VR
<i>P. farmeryi</i> ,	HT*	91.5 (1)	37.5 (.41)	35 (.38)	27.5 (sec. compr.)		1.5	5: —
<i>P. farmeryi</i> ,	Wr. 1979**	~73 (1)	~26 (.36)	~28.5 (.39)	~38 (.52)	1.33	~1.5	5: 15
<i>P. masiaposensis</i> ,	HT* (c)	96.0 (1)	36.0 (.38)	36.0 (.38)	47.0 (.49)	1.31	1.5	5: 16
<i>P. masiaposensis</i> ,	HT* (ic)				43.0 (.45)	1.19		
<i>P. rotalinus</i> ,	HT (ic)	89.5 (1)	32.5 (.36)	32.5 (.36)	37.0 (.41)	1.14	1.33	8: 12
<i>P. rotalinus</i> ,	HT (-160°)	74.0 (1)	26.5 (.36)	26.0 (.35)	29.5 (.40)	1.13	1.21	6: 12
<i>P. anapadensis</i> ,	LT (ic)	93.0 (1)	28.5 (.31)	37.0 (.40)	50.0 (.54)	1.35	1.35	5: 20
<i>P. anapadensis</i> ,	LT (c)	94.0 (1)	29.0 (.31)	37.5 (.40)	54.5 (.58)	1.45	1.36	5: 20

Abbreviated letters as for Table 1. ~ = approximate, ic = intercostal, c = costal

\* after Crick, 1910 or Collignon, 1955; Wr. 1979 = Wright, 1979, pl. 5, fig. 1; \*\* measured on photos; no mark = measured on actual specimen by myself.

which was listed by Houša as a species of *Menabonites*, has trituberculate ventral part in the late growth-stage. Some other species in his list of *Menabonites* have no or incomplete body chamber.

The whorl is much broader than high in '*Menabonites*' *anapadensis*, but the ratio of B/H may vary between species. For example, B/H of that species is indeed greater than that of *Ps. rotalinus* but not much different from that of *Ps. farmeryi* (see Table 2).

'*M.*' *anapadensis* looks to have denser, more numerous ribs than those of *Ps. rotalinus*, but again there is a considerable extent of variation among species in the rib density and also in the proportion between the number of major ribs with umbilical tubercles and that of all the ribs on the outer part. This is similar to the situation in various species of *Tongoboryceras*.

There is no significant difference in the pattern and complexity of sutures between *Menabonites* and *Pseudojacobites*. For instance, compare the suture of '*M.*' *anapadensis* (Kossmat, 1898, pl. 14, fig. 2) with that of *Ps. rotalinus* (*op. cit.*, pl. 14, fig. 3b) or *Ps. farmeryi* (see Wright, 1979, text-fig. 2; pl. 4, fig. 5; pl. 5, fig. 1).

On the ground of the above observations, *Menabonites* Houša, 1967 is not sufficiently distinct at generic level from *Pseudojacobites* Spath, 1922. The latter can be properly

defined so that it includes the species which were assigned to *Menabonites* by previous authors.

*Generic diagnosis of Pseudojacobites.*—Shell of moderate size, about 100 to 150 mm in diameter at full-grown stage. Whorls of moderate involution, encircling moderately wide or fairly narrow umbilicus, more or less broader than high, and reniform or subrounded in cross-section.

Ribs of unequal length and strength. Major ribs provided with tubercles at subrounded umbilical border or shifted outward near the mid-flank. Minor ribs intercalated or indistinctly branch from the longer ones. All the ribs curved forward at about the rounded ventrolateral shoulder and more or less projected on the venter. Periodic constrictions in front of some major ribs more or less distinct. Sooner or later in ontogenetic development there appear strong or weak ventrolateral tubercles on most of major and some of minor ribs. In addition to them, single or double mid-ventral tubercles occur in some species.

Sutures quite similar to those of *Tongoboryceras*.

#### Problem of dimorphism

Even if the generic diagnosis is given for each of *Tongoboryceras* and *Pseudojacobites*

as described above, there remains the problem of dimorphism about them.

I have already suggested, but not concluded, that in the family Pachydiscidae the 'bituberculate' (or 'trituberculate') and 'normal' forms might be considered as representing sexual dimorphism (Matsumoto, 1955, p. 155; 1979, p. 42), because the former is often smaller than the latter and species of both forms sometimes have common characters to a certain stage in ontogenetic development. At that date, however, I was inclined to interpret those small bituberculate genera as neotenous derivatives of 'normal' pachydiscids. Recently Kennedy (1986, p. 32) has given a general review on this problem. When the evidence is enough for the interpretation of sexual dimorphism, he dares to conclude the nomenclatorial sorting (dimorphic pairs regarded as synonyms) and in the cases where uncertainty exists he maintains a conservative approach. I would agree with Kennedy in principle, but the judgment whether the evidence is sufficient or not may vary between authors.

Now, how should I do about *Pseudojacobites* and *Tongoboryceras*? They have generally common characters and the main difference is the presence of ventrolateral (and in some case also ventral) tubercles in the former.

Some of the species of *Tongoboryceras* were established on incompletely preserved specimens. For instance, the holotype of *T. tongoboryense* is wholly septate (see Collignon, 1955, pl. 2, fig. 3) and the diameter of the adult shell of this species is not known. Collignon (1955, p. 26) mentioned that this holotype is comparable in size approximately with the middle aged specimen of *T. beantalyense* (Collignon). Incidentally, Houša (1967) referred *Lewesiceras beantalyense* to his *Menabonites*, but Collignon did not describe the presence of ventrolateral tubercles. The holotype of the latter species was explained as adult by Collignon (1955, pl. 2, fig. 2) but is 72 mm in diameter and wholly

septate. A larger example in his later publication (Collignon, 1965, pl. 427, fig. 1771) is 100 mm in diameter at the end of the preserved part of the body chamber which occupies a half of the outer whorl. This is nearly the same size as the holotype of *Pseudojacobites farmeryi* and that of *P. anapadensis*.

As far as the available material is concerned, no significant difference in size is recognized between *Tongoboryceras* and *Pseudojacobites* (see Tables 1, 2). At specific level well comparable counterparts are not found in the two genera. In other words, it is difficult to point out any possible candidate of a pair of microconch and macroconch in the hitherto described species of *Pseudojacobites* and *Tongoboryceras*.

*Pachydiscoides* Spath, 1922, with *Sonneratia janeti* de Grossouvre, 1894 (see Kennedy, 1984, p. 37, pl. 13, figs. 1-4) as the type species, is a small to medium sized but strongly ornamented pachydiscid genus of Coniacian to Santonian ages. Nearly contemporary *Tuberodiscoides* Collignon, 1966, with *T. termierorum* Collignon 1966 (p. 31, pl. 468, figs. 1910-1912) as the type species, is of similar size and allied to *Pachydiscoides* but has ventrolateral and siphonal tubercles. They might be regarded as microconchs but no counterpart macroconchs are known.

On the ground of the above observations, it is still difficult to lead a general conclusion as to the problem of dimorphism in the Pachydiscidae, especially with regard to earlier members of the family.

### Description of a new species

#### Genus *Eupachydiscus* Spath, 1922

*Type species.*—*Ammonites isculensis* Redtenbacher, 1873 by original designation (Spath, 1922, p. 124).

*Remarks.*—A new species described below is, in my opinion, interesting to the problem of the ancestry of the genus *Eupachydiscus*. Spath (1922, p. 124) thought of *Nowakites*

Spath, 1922 as ancestral to *Eupachydiscus*, but I regarded it as ancestral to *Canadoceras* Spath, 1922 (see Matsumoto, 1979, p. 37, fig. 5), although I did not discuss the line of descent at specific level. Houša (1967, p. 44) presumed *Lewesiceras plicatum* Houša, 1967 as a possible origin of *Eupachydiscus*, though with a query.

The suture of *Eupachydiscus* is much more complex than that of *Lewesiceras* and closer to that of *Tongoboryceras*. With respect to the shell-form and ornamentation, the young to middle aged whorls of some species of *Eupachydiscus*, e.g. *E. haradai* (Jimbo, 1894) (see Matsumoto, 1954, p. 281, figs. 14–17; pl. 9, figs. 1–3; pl. 10, figs. 1–3), are fairly similar to the middle to late whorls of certain species of *Tongoboryceras*, such as *T. satoi* (Matsumoto) (1979, p. 35, fig. 3; pl. 5, fig. 1). An ammonite rarely found by M. Kera from the Coniacian of Hokkaido deserves description in this respect.

*Eupachydiscus keramasatoshii*, sp. nov.

Figures 3, 4

*Holotype*.—No. 482 of Masatoshi Kera's Collection, obtained on October 2, 1988 from a nodule loose in the upper reaches of a stream called the Masago-zawa, a tributary to the Shuparo, i.e. the upper course of the River Yubari in the Yubari Mountains, central Hokkaido. It is to be kept in the Museum of Mikasa City.

*Description*.—Adult shell slightly exceeding medium size. Whorl expands with rather low rate and its degree of involution moderate (i.e. about a half). Umbilicus of moderate width encircled by steep and fairly high wall; umbilical shoulder subrounded, but for subangular edge of the major ribs in the late growth-stage.

Whorl of the septate stage fairly depressed,

with inflated flanks and broadly rounded venter. In the adult body chamber, B/H decreasing to a little below 1.2, with moderately rounded venter.

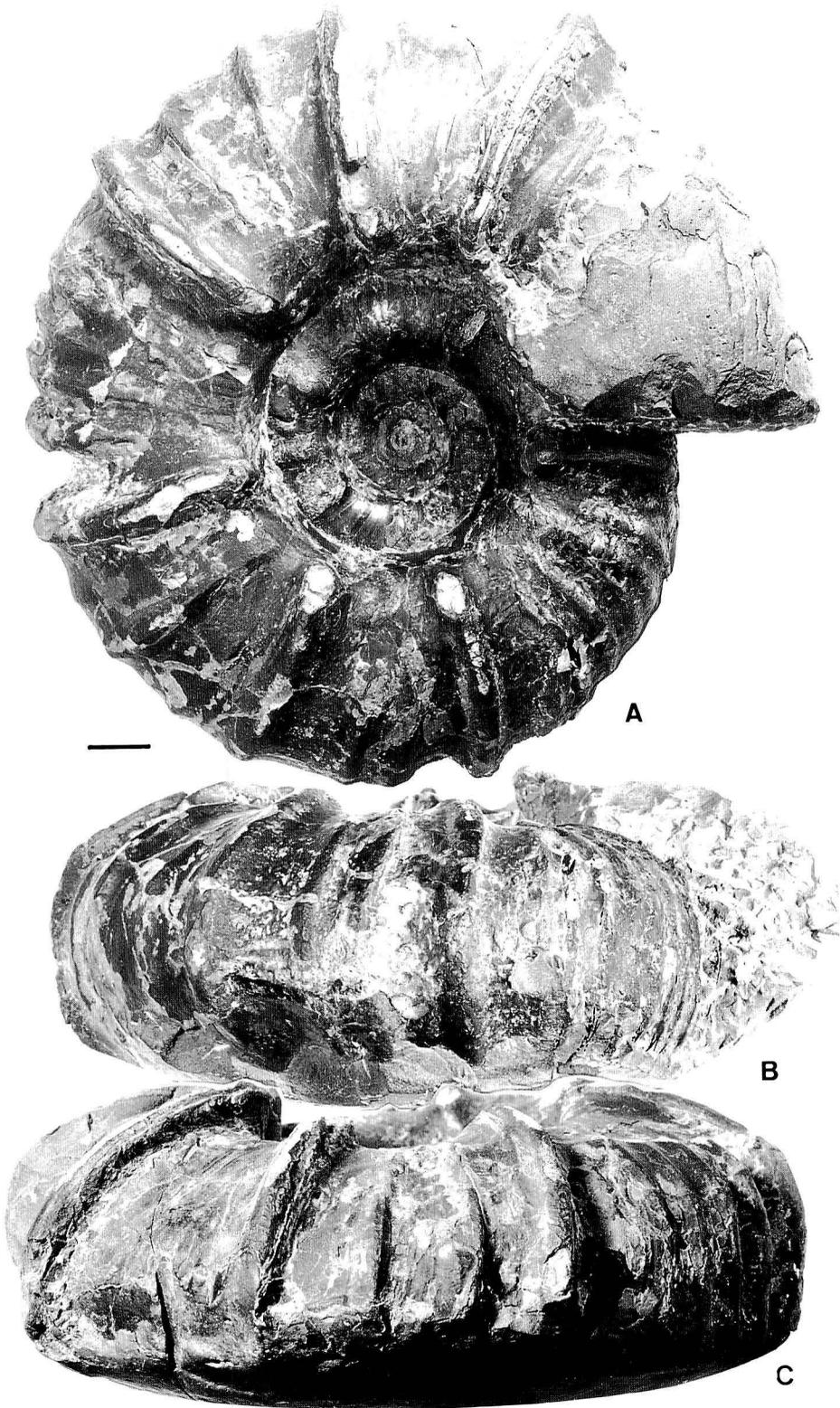
The exposed part (i.e. inner flank) of the very early whorls looks smooth. The umbilical bullae begin to appear at the point  $2 + 3/4$  whorls adaptically from the preserved end, i.e. at  $D =$  about 20 mm (inferred); very weak in the early half whorl, becoming somewhat more distinct at the umbilical shoulder in the next half whorl; altogether 9 to a whorl.

In the next stage, that is from the point  $1 + 3/4$  whorls adaptically from the preserved end to the early part of the outer whorl (inferred  $D =$  from 40 mm to 80 mm) and can be called the middle stage, major ribs occur at each  $50^\circ$  or  $60^\circ$  and are thick, strong, fold like and provided with prominent tubercles at the umbilical border, forming a gently concave curve on the flank and a broad convexity across the venter. Some of them may accompany a constriction. There are several minor ribs of unequal length on each interspace of major ones. One of them may be longer than others and nearly reaches the umbilical border where a weak bulla may be formed; some of shorter ones branch from the longer one and others are intercalated. All the ribs gently concave or slightly flexuous on the flank and cross the venter with a gently forward convexity.

In the whorl for about  $260^\circ$  of the adult stage, from the last portion (about  $50^\circ$ ) of the phragmocone to the end of the body chamber (which occupies  $210^\circ$ ), the major ribs much strengthen to nearly rectiradiate bar like flares, crossing the venter with increasing height, whereas minor ribs on the interspace of major ones become fewer, narrower and more widely separated, crossing the venter nearly straightly. Constrictions in front of some major ribs persist to the early part of the body chamber. The tubercles at the umbili-

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→ **Figure 3.** *Eupachydiscus keramasatoshii*, sp. nov. Lateral (A), frontal (B) and back (C) views of the holotype, collected by M. Kera from the Masago-zawa. Bar: 10 mm. (Photos by courtesy of Dr. M. Noda)



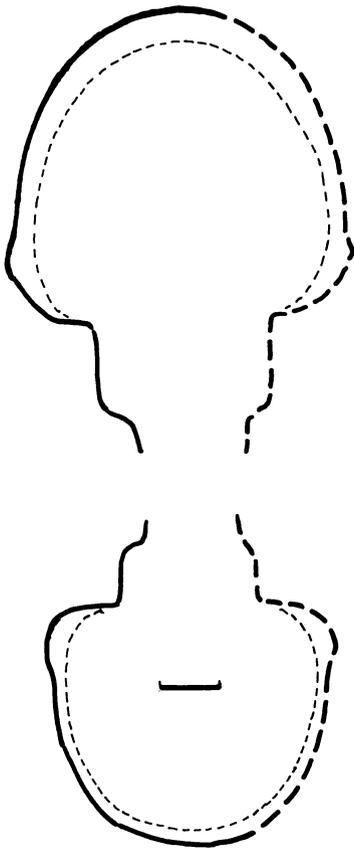


Figure 4. *Eupachydiscus keramasatoshii*, sp. nov. Whorl-section of the holotype. Bar: 10 mm. (T.M. *delin.*)

cal edge of major ribs are prominent and bullate.

Lobes and saddles of the suture in the late growth-stage are deeper or higher than broad, with narrowed stems and branches of lateral saddles, by deep and fine incisions.

*Dimensions.*—See Table 3.

*Observations.*—This specimen is nearly complete in showing the body chamber up to the peristome, provided that the minor rib in front of the strongly flared, last major ribs is regarded as an apertural flange. On this assumption the body chamber is  $210^\circ$ . The shell diameter is 127 mm at the preserved end (*i.e.* presumed peristome) and 135 mm at the last major rib. Conventionally I define the size of ammonite with diameter from 75 mm

to 125 mm as *moderate* (see Matsumoto, 1954, p. 246; 1988, p. 4). This ammonite slightly exceeds the defined moderate size, being near the lowest limit of the next size, *i.e.* *fairly large* (D over 125 mm up to 250 mm).

This specimen is embedded and fused with the rock matrix on its right side for a taphonomical reason, but the venter of its outer whorl is fairly well, if not completely, exposed. Therefore the whorl-breadth (B) is calculated from its measured half.

The specimen is covered with altered shelly layers for the major part, except for the summits of some ribs, peaks of tubercles and other minor portions. For this reason the major ribs and tubercles may generally look pronounced, as compared with the case of internal mould, whereas the suture is hardly traced as a continuous line but observable here and there.

The ornamentation in the adult whorl is characteristic. Of the six major ribs, the first two are fold like and essentially similar to but somewhat stronger than those of the preceding stage, weakly concave forward on the flank and very gently convex on the venter; the last three on the later half of the body chamber are much elevated and can be called flares which are almost vertical on the rear side and steeply inclined to the anterior; the third one shows a transitional feature from the fold like earlier ones to the bar like later ones. There is no minor rib on the interspace between the last two major ribs, except for very feeble lirae; there are only two minor ribs in the next preceding broad interspace. Several minor ribs on still earlier three major interspaces are somewhat irregular in length, breadth, spacing and curvature (see Figure 3). In the gross the irregularities may express transitional features from the minor ribbing of the middle growth stage to that of the late part of the adult stage.

*Comparison and discussion.*—This specimen is similar in the characters of its middle growth-stage to the holotype and subsequently illustrated specimens of *Tongoboryceras*

**Table 3.** Measurements (in mm) of *E. keramasatoshii* and selected examples of *Eupachydiscus*.

Species	Specimen	D	U	H	B	B/H	H/h	MR : VR
<i>E. keramasatoshii</i>	HT, Last rib (c)	135 (1)	47 (.35)	49 (.38)	58 (.43)	1.18	1.26	4 : 13
	HT, Last -10° (ic)	124 (1)	46 (.37)	42 (.34)	49 (.39)	1.17	1.17	4 : 14
	HT, Last -90° (ic)	115.5 (1)	39 (.34)	41.5 (.36)	49 (.42)	1.18	1.19	3 : 16
	HT, Last -180° (c)	100 (1)	33 (.33)	42 (.42)	53 (.53)	1.26	—	4 : 18
	HT, Last -190° (ic)	—	—	37	47	1.27	—	3 : 18
	HT, Last -270° (c)	—	—	34	44	1.29	—	4 : —
<i>E. isculensis</i> ,	HT* (c)	185 (15)	50 (.27)	80 (.43)	74 (.40)	0.93	1.45	7 : 18
<i>E. isculensis</i> ,	Imm.*	78 (1)	20 (.26)	36 (.46)	28	—	—	7 : 21
<i>E. haradai</i> ,	LT	120 (1)	32 (.27)	48 (.40)	55 (.46)	1.15	1.20	6 : 14
<i>E. haradai</i> ,	T.M.	198 (1)	51 (.26)	80 (.40)	87 (.44)	1.09	1.19	7 : 17
<i>E. haradai</i> ,	Usher	101 (1)	23 (.23)	44 (.44)	50.5 (.50)	1.15	1.29	6 : 15
<i>E. teshioensis</i> ,	HT	252 (1)	67 (.27)	108 (.43)	123 (.49)	1.14	1.40	6 : 16
<i>E. roederi</i> ,	HT (ic)*	150 (1)	47 (.31)	61 (.41)	74 (.49)	1.21	1.45	7 : 11

Abbreviated letters or symbols as for Tables 1, 2. LT=lectotype; Imm.=Immel *et al.*, 1982, pl. 8, fig. 2\*; T.M.=Matsumoto, 1954, pl. 24, fig. 2; Usher=Usher, 1952, pl. 14.

*rhodanicum* from the Upper Turonian of France and England (*loc. cit.*), but the major ribs are coarser, disposed at wider intervals and provided with stronger umbilical tubercles in the former than in the latter. In other words, the difference in the coarseness or intensity between major and minor ribs in the middle aged whorl of this species is greater than that in the middle to late whorl of *T. rhodanicum*. As regards *T. rhodanicum*, the full length of the adult body chamber is not preserved in the hitherto described specimens. In the outer whorl of a fine example from the Chalk Rock (Wright, 1979, pl. 6, fig. 1) only the beginning of the body chamber is preserved. The ribs seem to strengthen gradually from the late part of the phragmocone, and the sudden appearance of prominent major ribs and the contrasted reduction of minor ribs as seen on the body chamber of M. Kera's specimen do not likely occur in that species.

In the typical species of *Eupachydiscus*, such as *E. isculensis* and *E. haradai*, the major tuberculate ribs and minor intercalated or branching ribs are both strengthen gradually and fold like instead of bar like. *E. haradai*, with which *Pachydiscus perplicatus* Whiteaves, 1903 (see Usher, 1952) is a syno-

nym (see Matsumoto, 1959, p. 33), may be one of the best studied species of this genus. It shows the ontogenetic changes from a much depressed, reniform young whorl with fine and weak ornaments, via middle aged whorl with moderate characters, to the less depressed, more rounded whorl with strong ornaments of typical *Eupachydiscus* type, which may be called the adolescent or early substage of the adult stage. In the whorl of still later stage strong, nearly rectiradiate major ribs predominate, with few or no intercalated minor ones. This is exemplified by the outer whorl (though incomplete) of GK. H3405 (Matsumoto, 1954, pl. 9, fig. 1), whereas the lectotype of *E. haradai* is wholly septate. Anyhow, the adult shell of that species is much larger than the Kera's specimen and its major ribs are thick and fold like instead of bar like flared ones of the latter.

Incidentally, the specimens from the Coniacian and Lower Santonian of Austria described under *E. isculensis* are all small or medium-sized (Herm *et al.*, 1979; Immel *et al.*, 1982), although they preserve the body chamber at least partly. They are fairly similar to such species as *T. satoi* mentioned above.

*Eupachydiscus roedereri* (Collignon) (1938, p. 12, pl. 2, fig. 3; pl. 3, fig. 1 under *Canadoceras*; 1970, p. 26, pl. 617, fig. 2302 under *Hoepenites*), from the Campanian of Madagascar, has widely spaced, rather recti-radiate, bar-like major ribs, but this kind of ribbing begins to develop from the earlier growth-stage and persists for longer period and the mode of spacing is more regular than the bar-like ribs of the M. Kera's specimen.

To sum up, M. Kera's specimen is so distinctive that a new species is established on it, although it is solitary. This species retains some characters which resemble those of certain species of *Tongoboryceras* but it does show new characters, such as prominent tubercles from middle growth stage and strong major ribs on the adult body chamber with decreasing B/H, which allow me to refer

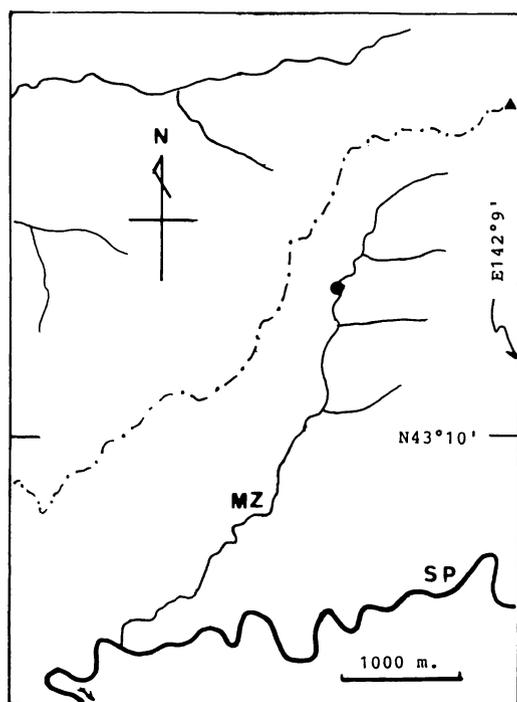
it to *Eupachydiscus*.

**Occurrence.**—The holotype was obtained by M. Kera loose at loc. Y5512 in the upper reaches of the Masago-zawa, a branch of the River Shuparo (Figure 5). The stream runs with some meandering along a V shaped valley roughly in parallel to the trend of the strata of mudstone with some interbeds of sandstone. *Inoceramus uwajimensis* Yehara occurs abundantly in several layers and numerous nodules in the mudstone. Also *Didymotis akamatsui* (Yehara) is found at a nearby locality (Y5507) and Y. Kawashita obtained a gigantic macroconch of *Mesopuzosia yubarensis* (Jimbo) at loc. Y5518. The described ammonite is certainly of Coniacian age, being an oldest example of *Eupachydiscus*.

**Acknowledgements.**—I very much appreciate Mr. Masatoshi Kera's generosity to provide the ammonite of his collection for this study. He kindly helped me, together with his brother Mr. Yasuji Kera, in a field work in the upper reaches of the Masago-zawa. Mr. Yoshitaro Kawashita, Dr. Seiichi Toshimitsu and Dr. Masayuki Noda also did another field work with me in the same area, although I failed to find more specimens of the present species. Miss Akiko Murakami assisted me in preparing the typescript.

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**Figure 5.** Map of the Masago-zawa (MZ), a tributary to the River Shuparo (SP), indicating the ammonite locality (Y5512) with a small solid circle. Chain: the water shed with a peak of 695 m at the mark of solid triangle. For the north western part see fig. 86 in Matsumoto, 1988.

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北海道産パッキディスク科の興味あるアンモナイトならびに関連属種についての所見: Pachydiscidae の属レベルの分類はまだ定着していない。*Lewesiceras* は縫合線の各要素が幅広く刻みが浅いものに限定するべきだ。中程度に幅狭く刻みが深いものは *Tongoboryceras* に入れた方がよい。例えば *L. satoi*, *L. kawashitai* は後者に移す。所属種の増加に伴い *T.* 属のもとの定義を若干改正した。同属に似るが生長後期に外側の肩, 種によってはさらに外面中央に突起があるものは, *Menabonites* または *Pseudojacobites* とされていた。*M.* 属の所属種を検討し, *Ps.* に *M.* を包含した内容で *Ps.* の再定義を提唱した。本科において突起が外側にもあるものは普通のものより小型の場合が多く, 近年これを性的二型と解釈する説が強くなっている。しかし *T.*, *Ps.* 両者の場合には大きさの差がなく, 対応種の好例も見当たらない。

*T. rhodanicum* や *T. satoi* の生長過程の中・後年は *Eupachydiscus haradai* などの幼・中年と似るが, 後者の成年殻は大型でかつ装飾が強化し, 縫合線も複雑になる。最近解良正利が北海道夕張の真砂沢のコニアシアン(*I. uwajimensis* 帯)から得た資料はチュロニアン上部産の *T. rhodanicum* からの分岐を想定でき, 成年殻がそれほど大型でなく, かつ特異な形質を示すので, 新種 *E. keramasatoshii* として記載した。松本達郎

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## 909. EARLY LIFE HISTORY OF TWO MIDDLE PLEISTOCENE SPECIES OF *LIMOPSIS* (ARCOIDA : BIVALVIA)\*

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**Abstract.** Early life history of two species of *Limopsis*, *L. (Crenulilimopsis) oblonga* (A. Adams) and *L. (Limopsis) azumana* Yokoyama is discussed on the basis of well-preserved Middle Pleistocene juvenile specimens from the southwestern Kanto region, central Japan. *L. (C.) oblonga* has a relatively large prodissoconch I (Pd I) (ca. 180  $\mu\text{m}$  in length) and a well-marked prodissoconch II (Pd II), suggesting lecithotrophic development with a short pelagic stage. *L. (L.) azumana*, in contrast, probably underwent direct development or ovoviviparity because of its unusually large prodissoconch (ca. 400  $\mu\text{m}$  in length) without Pd II stage. The two species exhibit a similar pattern in hinge development: the hinge in the full-grown prodissoconchs is made of a long, uninterrupted series of ligamental pits (provinculum), and anterior and posterior cardinal teeth appear at the early dissoconch stage, increasing their number as the shell grows. Predominance of minute shells at the fossil locality strongly suggests an extremely high juvenile mortality in the two species.

**Key words.** Bivalvia, *Limopsis*, Early life history, Pleistocene, Ninomiya Group, Kanto Region.

### Introduction

The shells of bivalve molluscs consist of two different portions, prodissoconch and dissoconch (Werner, 1939; Rees, 1950; Ockelmann, 1965). The prodissoconch is secreted before metamorphosis, and is clearly distinguished from the subsequent dissoconch by the abrupt change in surface ornamentation at the prodissoconch-dissoconch boundary (Jablonski and Lutz, 1980, 1983). Ontogenetic studies of modern bivalve species by culture methods have shown that the prodissoconch and early dissoconch provide considerable information on the early life history of the organisms (e.g. Thorson, 1936; Yoshida, 1953; Loosanoff and Davis, 1963; Chanley, 1965, 1966, 1969, 1970; LaBarbera and Chanley, 1970, 1971).

In spite of the potential usefulness of mol-

luscan larval shell morphology in paleobiological research, investigation on fossil bivalves is quite limited (LaBarbera, 1974; Lutz and Jablonski, 1978; Tanabe and Zushi, 1988; Palmer, 1989), owing much to the rare occurrence of juvenile specimens including prodissoconchs in many fossil bivalve assemblages.

In this paper, I describe the mode of occurrence and the morphological features of well-preserved juvenile shells of two species of *Limopsis*, *L. (Crenulilimopsis) oblonga* (A. Adams) and *L. (Limopsis) azumana* Yokoyama from the Middle Pleistocene Ninomiya Group in southwestern Kanto region, and discuss their implications for early life history.

### Materials and methods

**Materials.**—Middle Pleistocene marine deposits of the Ninomiya Group (Otuka,

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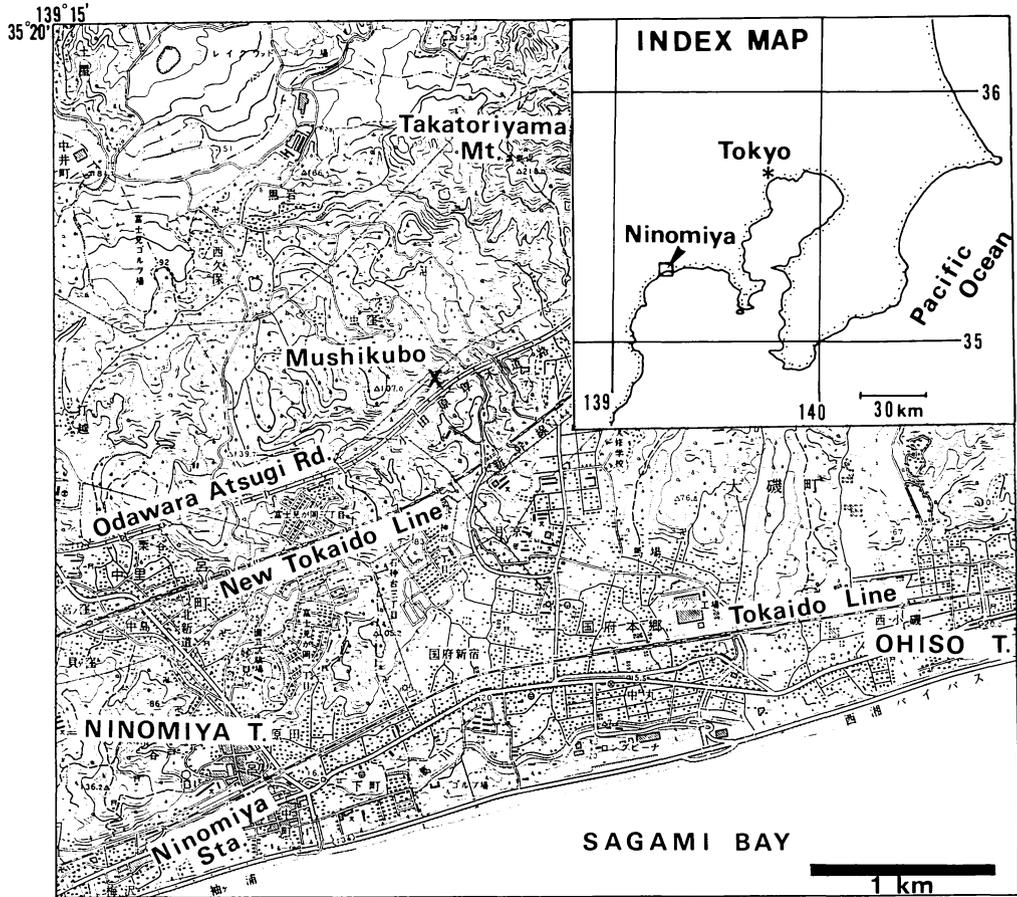


Figure 1. Map of Ninomiya area, showing the fossil locality (X).

1929) are distributed in the Ohiso Hill area, southwestern Kanto region. The middle part of the group (Lower Shimoda Formation; Mori and Osada, 1979) yields abundant molluscan fossils, and the molluscan assemblages of the formation were compared with the Middle Pleistocene Naganuma fauna in Yokohama area by previous authors (Yokoyama, 1926; Otuka, 1929; Mori and Osada, 1979).

Juvenile shells of *L. (Crenulilimopsis) oblonga* and *L. (Limopsis) azumana* utilized were collected from the fine sand beds in the upper part of the formation exposed at Mushikubo, about 2.5 km northeast from JR Ninomiya Station, together with many middle- to large-sized specimens (Figure 1; same locality as Loc. 11 of Mori and Osada, 1979).

Figured specimens are stored at University Museum, University of Tokyo (UMUT).

Incidentally, *L. (L.) azumana* is an extinct species, established by Yokoyama (1910) for small, oblique, and inequilateral specimens with a smooth inner margin from the early Pleistocene Koshiba Formation in Yokohama City. These features are commonly observed in the examined material from the Ninomiya Group. Later authors attributed the subgeneric and generic positions of this species to *L. (Nipponolimopsis)* (Habe, 1951; Taki and Oyama, 1953; Oyama, 1973) or *Nipponolimopsis* Habe, 1951 (Habe, 1973), but the diagnostic characters of Habe's (1951) *Nipponolimopsis*, especially incised inner margin and surface ornamentation consisting of concentric and radial ribs, are not present in

the type specimens of *L. azumana* (UMUT CM 26402, 26403), although fine radial lirae crossed by concentric ribs faintly occur in both the type and the Mushikubo specimens. I treat the generic and subgeneric positions of this species as *Limopsis* (*Limopsis*) by reason of the smooth inner margin and the absence of prominent radial ornamentation.

**Methods.**—A block of fossil-bearing sands of 2,000 cm<sup>3</sup> in volume (20×10×10 cm) was collected from the locality. A small amount of sands (35 cm<sup>3</sup>) was removed from the bulk sediment sample. After having dried and dispersed the sand particles, juvenile shells of bivalves were picked up carefully with a fine brush from sediments scattered on a laboratory dish under a binocular microscope. The remaining sediment sample was wet-sieved through a 500 μm diagonal mesh screen, and fossil molluscs were removed from residues under a binocular microscope. Juvenile shells of *L. (C.) oblonga* and *L. (L.) azumana* were identified by successively correlating the large individuals with smaller ones on the basis of overall morphology, size and hinge structure at the prodissoconch and early dissoconch stages. Total number of juvenile shells for each species in the bulk sediments was calculated from the number in a unit sediment (35 cm<sup>3</sup>). Besides the above two species, *Glycymeris rotunda* (Dunker) occurs abundantly at the fossil locality. Juvenile shells of this species are more or less similar in the prodissoconch morphology and hinge structure to those of *L. (C.) oblonga*, but are distinguished from the latter by possessing a more rounded, equilateral shell outline. Other bivalve species from the locality (e.g. *Nemocardium samarangae*, *Paphia naganumana*, *Solen grandis*, *Macoma tokyoensis*) are quite rare in occurrence, and their juvenile shells are easily distinguished from those of the two limopsids in having different hinge structure.

Selected juvenile shells of the two species were coated with platinum using an ion coater, and their external morphology and

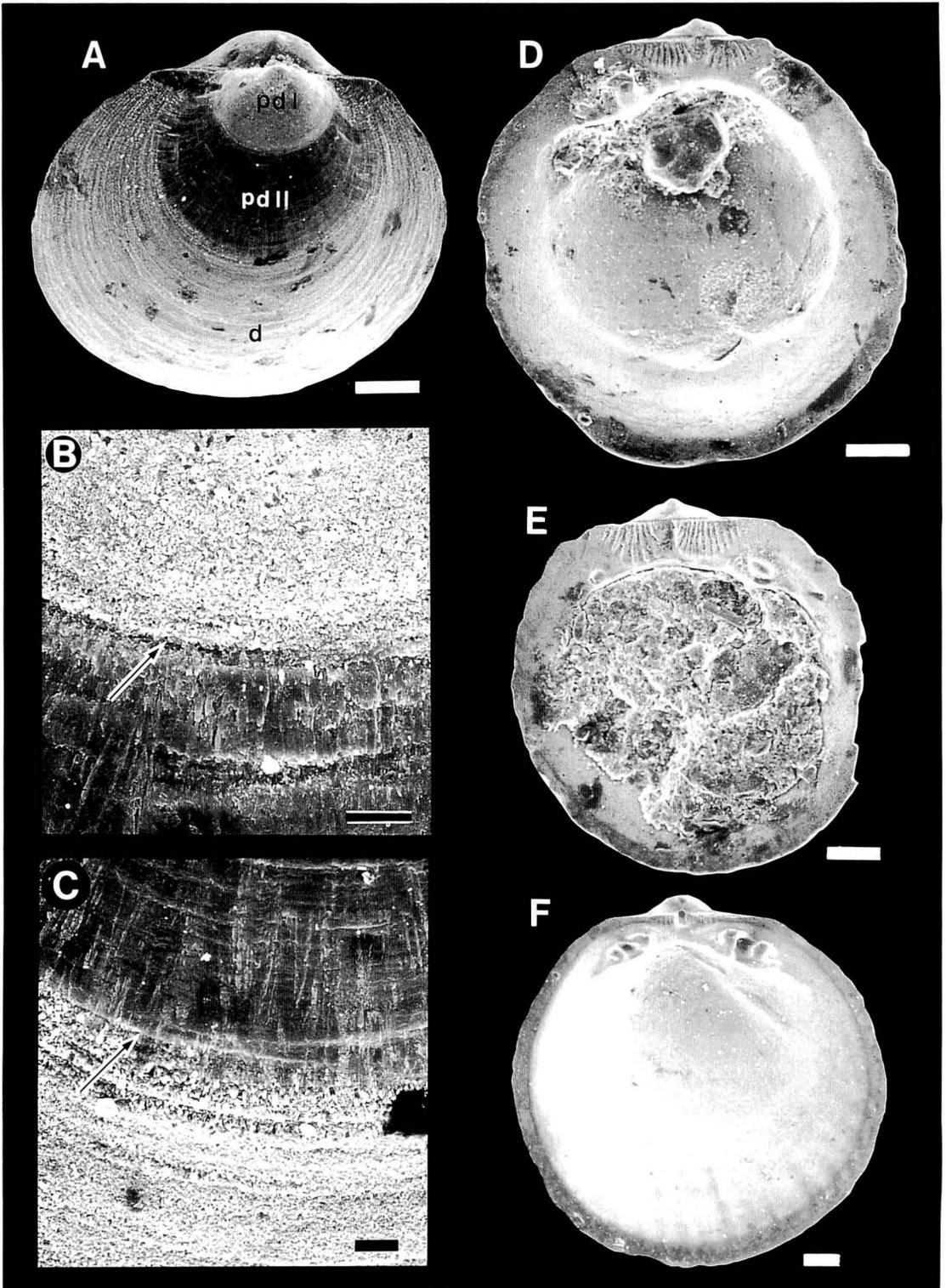
hinge structure were examined by means of a scanning electron microscope (Hitachi, model S-430). Juvenile shell growth in the Bivalvia is divided into three ecologically and morphologically well-defined stages, i.e. prodissoconch I (=initial shell secreted by the shell gland and mantle epithelium during the stage developing from the non-shelled trochophore stage for species with larval stage or during the embryonic stage for species without larval stage), prodissoconch II (=the shell deposited by the mantle edge during the pelagic stage), and dissoconch (=the shell formed after metamorphosis) (Werner, 1939; Rees, 1950; Ockelmann, 1965; Carriker and Palmer, 1979; Jablonski and Lutz, 1980, 1983). I recognized these stages in the two limopsids on the basis of definition by Ockelmann (1965) and Jablonski and Lutz (1980).

#### Juvenile shell morphology

*Limopsis (Crenulilimopsis) oblonga.*—As in the other species with a larval stage, the prodissoconch of this species is divided into prodissoconch I and prodissoconch II (Figure 2-A). The prodissoconch I is characterized by the D-shaped outline, coarse and punctate surface without growth lines, more or less projected umbonal region, and the rather long and straight hinge line (Figures 2-A, B). Its length ranges from 170 μm to 200 μm in the present material.

The prodissoconch II is well developed, measuring at about 200 μm in height. The surface ornament consists of fine and dense concentric growth lines and fine radial striations (Figures 2-B, C). The prodissoconch II-dissoconch boundary is clearly distinguished by the abrupt expansion of concentric growth lines and coarsening of surface texture (Figure 2-C). The above features in the prodissoconch stage of the Middle Pleistocene form are essentially identical with those of the Upper Pliocene one described by Tanabe and Zushi (1988).

Hinge development in the prodissoconch



stage is uncertain, because no true prodissoconchs were found in the present material. Early dissoconchs of approximately 0.5 mm length possess a well-marked cardinal tooth on both anterior and posterior edges of the hinge (Figures 2-D, E). Judging from this fact, the hinge in the prodissoconch stage probably consists only of a series of primitive ligament pits (provinculum), as in the larvae of other Pteriomorphia (Rees, 1950; Le Pennec, 1976, 1980; Siddall, 1978; Lutz and Hidu, 1979). Juvenile shells of approximately 1 mm length have two anterior and posterior cardinal teeth, increasing their number as the shell grows (Figure 2-F).

The inner ventral margin is smooth in the shells of about 0.6 mm length, but it is distinctly crenulated in the shells larger than 1 mm length (Figure 2-F).

*Limopsis (Limopsis) azumana*.—This species possesses an unusually large prodissoconch I ranging from 400  $\mu\text{m}$  to 450  $\mu\text{m}$  in length. It has a D-shaped outline with a broadly rounded ventral margin and a long and straight hinge line (Figures 3-A, D). The mid-portion is markedly inflated with an elliptical flat crest, from which many radial striations extend marginally (Figure 3-B).

Prodissoconch I is followed by dissoconch without prodissoconch II stage. The prodissoconch I-dissoconch boundary is clearly marked by the presence of a conspicuous constriction (arrows in Figures 3-A, C). The dissoconch is ornamented with many concentric growth bands (Figures 3-A, C).

At the prodissoconch I stage dentition is absent. The hinge apparatus (provinculum) of the fully grown prodissoconch (ca. 450  $\mu\text{m}$  length) is long and straight (ca. 330  $\mu\text{m}$  length), and consists of a series of ligamental

pits (Figure 3-D). Cardinal teeth appear on the anterior and posterior edges of the hinge at the early dissoconch stage (ca. 0.8 mm in length; Figure 3-E). Dissoconchs of 1.2 mm in length have two anterior and posterior cardinal teeth (Figure 3-F).

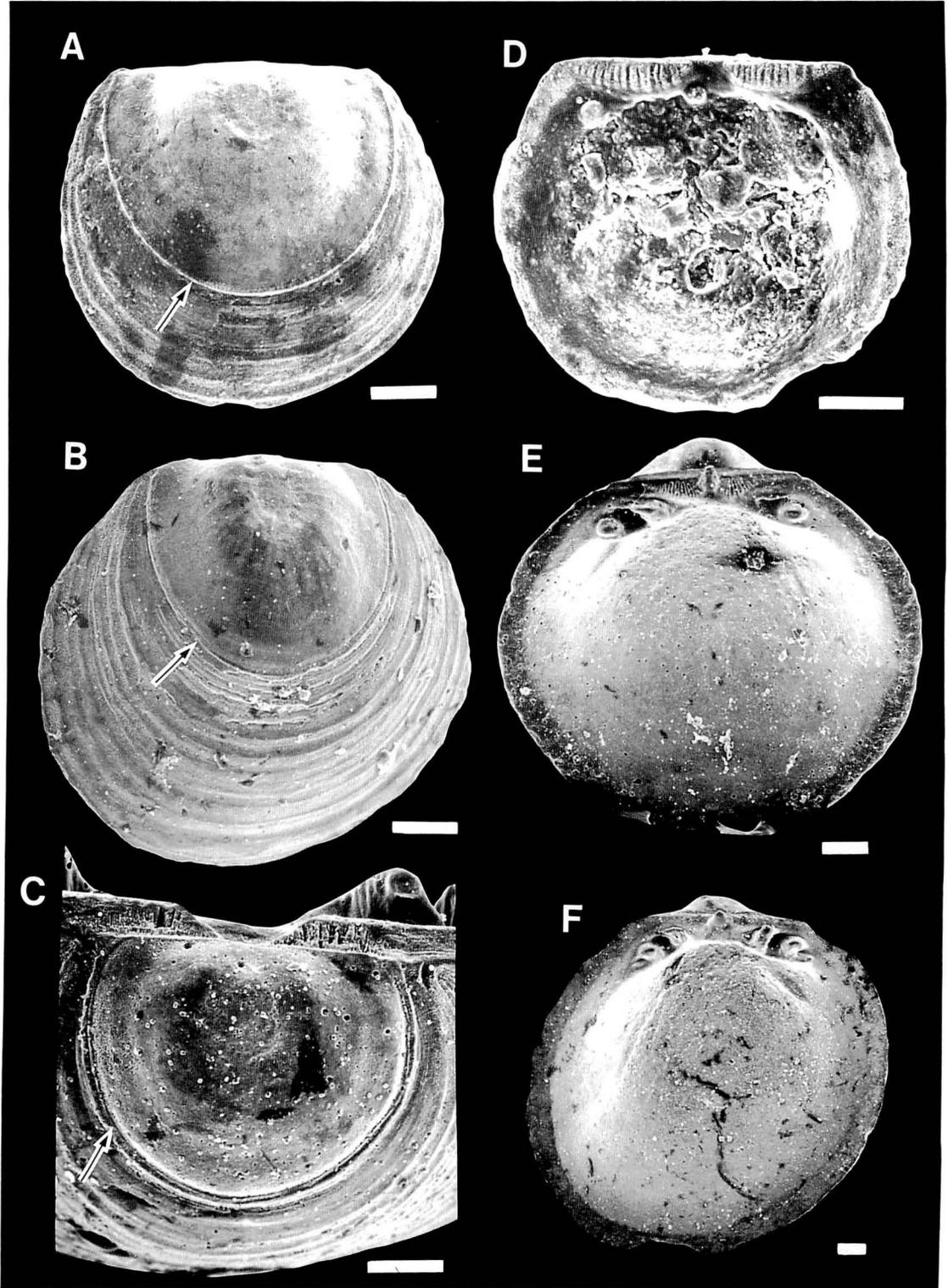
The inner shell margin is smooth throughout the whole stage of ontogeny.

### Mode of occurrence

Juvenile shells of *Limopsis (Crenulilimopsis) oblonga* and *L. (Limopsis) azumana* from Mushikubo locality are found in a good state of preservation, retaining detailed shell features. Similar evidence is also recognized in the large-sized specimens of the two species from the same locality. For example, the sample of *L. (C.) oblonga* larger than 4 mm in shell length in the sand block of 2,000  $\text{cm}^3$  consists of 73 articulated valves and 274 disarticulated valves (141 right and 133 left valves). Both articulated and disarticulated specimens of this species show no trace of abrasion on their shell surface, and furthermore, most specimens retain an organic ligament. Based on these lines of evidence, I regard the samples of the two limopsids from the fossil locality as virtually autochthonous, and empty shells have been accumulated over a period of time as a normal fossil population. The size frequency distribution of *L. (L.) azumana* from the fossil locality is characterized by a strongly right-skewed, negatively sloping distribution pattern, showing the predominance of small individuals (Figure 4). The numerical ratio of the minute shells less than 1 mm length to the total specimens reaches 95.5% (3885/4068).

The sample of *L. (C.) oblonga* consists of

← **Figure 2.** Scanning electron micrographs of juvenile shells of *Limopsis (Crenulilimopsis) oblonga* (A. Adams) from the Middle Pleistocene Lower Shimoda Formation at Mushikubo, Ninomiya Town, Kanagawa Prefecture. Outer (A-C) and inner (D-F) views. A. Articulated valves (UMUT RM18880-1). pdI: prodissoconch I, pdII: prodissoconch II, d: dissoconch. B. Part of A, showing the prodissoconch I-prodissoconch II boundary (arrow). C. Part of A, showing the prodissoconch II-dissoconch boundary (arrow). D. Right valve (UMUT RM18880-2), E. Left valve (UMUT RM18880-3), F. Left valve (UMUT RM18880-4). Scale bars indicate 100  $\mu\text{m}$  for A, D-F and 10  $\mu\text{m}$  for B-C.



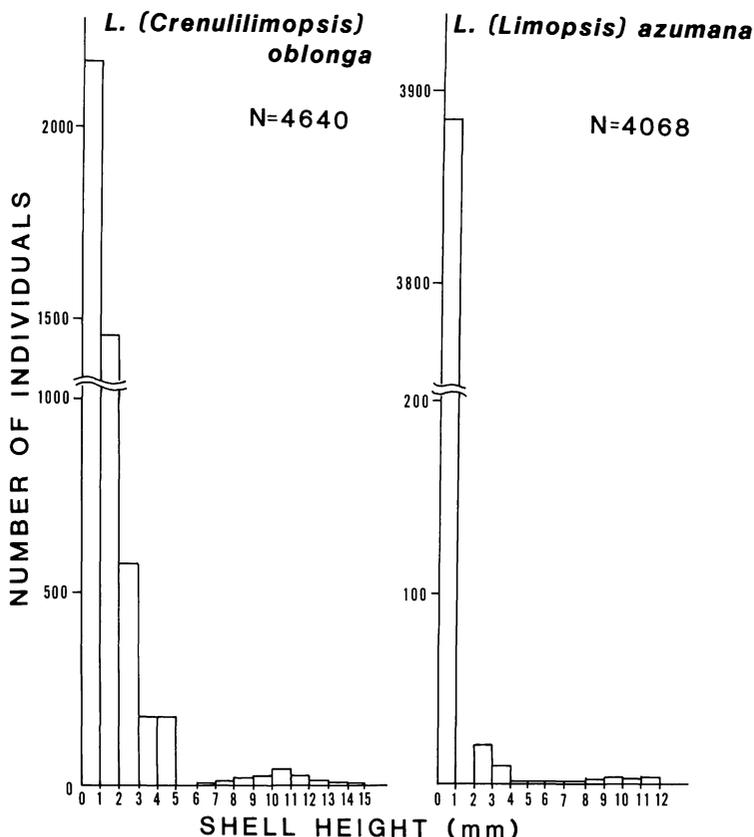


Figure 4. Size-frequency histograms of the shells of *Limopsis (Crenulilimopsis) oblonga* and *Limopsis (Limopsis) azumana* in a unit sediment sample (2,000 cm<sup>3</sup> in volume) from the fossil locality.

two clearly defined groups. The smaller group is represented by juvenile specimens less than 5 mm in length, showing the step-wise decrease in the frequency of occurrence with increasing shell size. This group occupies 97.2% for the numerical ratio to the total number of individuals (4512/4640). The larger group forms a broad and fairly symmetrical cluster with a peak at 10–11 mm. Similar abundant occurrence of juvenile shells is commonly recognized in many primary death bivalve assemblages in modern

environments (e.g. Powell *et al.*, 1984; Cummins *et al.*, 1986).

### Discussion

*Developmental types.*—The relationship between juvenile shell features and developmental types has been investigated in many Recent bivalve species from observation of early shell morphogenesis by culture methods (Thorson, 1936, 1946; Yoshida, 1953; Ockelmann, 1965; Sastry, 1965; Chanley, 1965,

← **Figure 3.** Scanning electron micrographs of juvenile shells of *Limopsis (Limopsis) azumana* Yokoyama from the Middle Pleistocene Lower Shimoda Formation at Mushikubo, Ninomiya Town, Kanagawa Prefecture. Outer (A–C) and inner (D–F) views of disarticulated valves. A. Early dissoconch (UMUT RM18881-1), B. Early dissoconch (UMUT RM18881-2), C. Enlarged view of early dissoconch (UMUT RM18881-3), D. Full-grown prodissoconch with a straight hinge (provinculum) (UMUT RM 18881-4), E. Early dissoconch (right valve) with a pair of cardinal teeth (UMUT RM18881-5), F. Early dissoconch (left valve) with two pairs of cardinal teeth (UMUT RM18881-6). Scale bars in all figures indicate 100 μm.

1966, 1969; Chanley and Chanley, 1970; LaBarbera and Chanley, 1970, 1971; Chanley and Andrews, 1971, among others). Ockelmann (1965) and Jablonski and Lutz (1980) documented some criteria to distinguish the developmental type of a given species from prodissoconch features. Based on the criteria by these authors, let us consider the developmental type of the two limopsids examined.

*Limopsis (Crenulilimopsis) oblonga* is an extant species known from lower sublittoral to upper bathyal zones off southwest Japan (Habe, 1977), but its early life history is virtually unknown because of the difficulty in rearing larvae in the laboratory. The Middle Pleistocene form of this species examined has a relatively large prodissoconch I, whose dimensions are comparable with those of Recent species with a short lecithotrophic larval stage (Ockelmann, 1965). This fact and the presence of a well-developed prodissoconch II stage seem to suggest that the Middle Pleistocene form of this species probably underwent lecithotrophic development with a short, non-feeding larval stage. The same interpretation was presented by Tanabe and Zushi (1988) for the Upper Pliocene form.

In contrast to *L. (C.) oblonga*, *Limopsis (L.) azumana* has an unusually large prodissoconch without prodissoconch II stage. This feature is common in many Recent bivalves without a pelagic stage. Therefore, I regard the developmental type of this species as direct development or ovoviviparity. A considerable number of marine bivalve species have been known to undergo direct development in association with brood-protection (Ockelmann, 1965). It remains uncertain whether *L. (L.) azumana* developed with brood-protection or not, because of the absence of reliable criteria from prodissoconch morphology on this problem. As described before, the mid-portion of prodissoconch I in *L. (L.) azumana* exhibits an elliptical flat crest and radiating striations

from its margin. The overall morphology is quite similar to that in the primary shells of conchiferan molluscs (Bandel, 1982). In Recent bivalves known to us, the primary shell consists of a single organic conch with oval outline (Waller, 1981; Bandel, 1988). The organic primary shell is secreted by the interior rudiment of the mantle (shell gland) during the pre-veliger stage, followed by deposition of the bivalved calcified shell beneath it (Bandel, 1988). Secretion of an oval to spherical organic primary shell by the interior shell gland prior to a mineralized shell has been confirmed in other molluscan groups (e.g. "cicatrix" in nautiloid cephalopods; Arnold *et al.*, 1987), and this suggests a similarity in basic morphogeneric program among conchiferan molluscs (Bandel, 1982, 1988).

*Juvenile mortality.*—Although early shell growth rate in bivalves greatly depends on many environmental factors such as ambient water temperature and food supply, previous studies on bivalve early shell growth in the laboratory have shown that most species attain 1 mm in shell length within 10–50 days after metamorphosis (Yoshida, 1964). This evidence seems to suggest that the small-sized shells in the fossil assemblages of the two species of *Limopsis* died immediately after settlement and added to the death assemblages.

Studies of molluscan living populations and death assemblages in modern environments have shown that a considerable number of juvenile empty shells is inputted in the death assemblage by natural mortality of newly settled spat (Powell *et al.*, 1984; Shimoyama, 1985; Cummins *et al.*, 1986). From comparative analysis of living populations and death assemblages of the thirteen bivalve species on the Texas coast by monthly sampling, Cummins *et al.* (1986) realized that the longest half-lives in any of these species are less than one year. In consequence, the expected size-frequency distribution of the primary death assemblage is char-

acterized by the predominance of empty shells of small, newly settled spat. Nevertheless, juvenile shells including prodissoconchs are seldom found in many fossil assemblages, as a result of their selective destruction and dissolution during the taphonomical process. The Middle Pleistocene samples of *L. (C.) oblonga* and *L. (L.) azumana* examined are, in this respect, quite unusual examples which preserve the properties of the original death assemblages.

The size-frequency distributions of the samples examined apparently suggest a much higher mortality rate in the juvenile stage than in the middle- to later-growth stages in the two species, especially in *L. (L.) azumana*. It is strongly postulated from this study that the two limopsids examined had equally high juvenile mortality, although they underwent different developmental histories.

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Koshiba 小柴, Mushikubo 虫窪, Naganuma 長沼, Ninomiya 二宮, Shimoda 下田.

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中部更新世 *Limopsis* 属二枚貝 2 種の初期生活史: *Limopsis* 属二枚貝 2 種, *L. (Crenullimopsis) oblonga* および *L. (L.) azumana* の初期生活史について, 神奈川県二宮町虫窪の中部更新統二宮層群中部産の保存のよい幼貝標本をもとに検討した結果, それぞれ卵栄養型, 直達発生もしくは卵胎生型の発達様式が推定された。さらに, 化石産地における化石稚貝の産状の検討から, 両種とも新規加入の初期段階できわめて高い死亡率を持っていたと考えられる。

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棚部一成

## 910. PLIOCENE-PLEISTOCENE MOLLUSCAN ASSOCIATIONS IN NORTH-CENTRAL JAPAN AND THEIR RELATIONSHIP TO ENVIRONMENTS\*

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**Abstract.** Seven major groups of molluscan associations are recognized in the Japanese cold water molluscan faunas ranging over about 5 million years from latest Miocene to Pleistocene. Each of the groups is composed of local associations which are similar not only in species or genus composition but also in environmental preference to one another, and accordingly are in ecologically parallel relationships with one another. The distribution of the association groups was controlled primarily by water depth and grain size of bottom sediments. Each of the fossil association groups has analogous living communities comparable in their composition and habitat around Japan. Among these seven groups the *Acila-Turritella* Association Group is the most prevalent and is the fossil representative of the lower sublittoral community. The *Delectopecten* and *Nuculana* Association Groups are interpreted as deeper dwellers. The *Anadara* and *Macoma-Mya* Association Groups represent shallow marine environments, comparable with sandy and muddy upper sublittoral faunas, respectively. Occurrence of the *Thyasira* Association Group may be related to a reducing environment. The *Chlamys* Association Group occupied coarse-grained sand bottoms of the lower sublittoral or upper bathyal zone.

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**Key words.** Cold water marine molluscs, faunal association, North-Central Japan, parallelism, Pliocene-Pleistocene.

### Introduction

Ecologically analogous faunal associations, which are similar to each other in taxonomic composition and environmental preference, are found among local benthic faunas of different ages and different areas (e.g., Chinzei and Iwasaki, 1967; Walker and Laporte, 1970; Hickman, 1984). This relationship seen among fossil associations is comparable with the ecological parallelism (Thorson, 1957) recognized among biogeographically isolated communities in the Recent marine bottoms. The relationship provides the framework for ecological comparison

among stratigraphically or geographically isolated faunas and a basis for understanding community evolution (Chinzei and Iwasaki, 1967; Chinzei, 1984; Walker and Laporte, 1970; Boucot, 1975, 1981).

The ecologically parallel relationship has been recognized among the faunas of three different ages in the Japanese Neogene, namely early Middle Miocene, Middle Miocene and Pliocene (Chinzei and Iwasaki, 1967; Chinzei, 1978). In muddy tidal flat sediments, for example, there appear associations of the *Crassostrea* bank in all of the three ages. These parallel associations may be treated as an association group which corresponds to the muddy tidal flat environment. Four major association groups representing

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the tidal flat to subtidal shallow environments are known in the shallow marine sediments of the Japanese Neogene (Chinzei and Iwasaki, 1967).

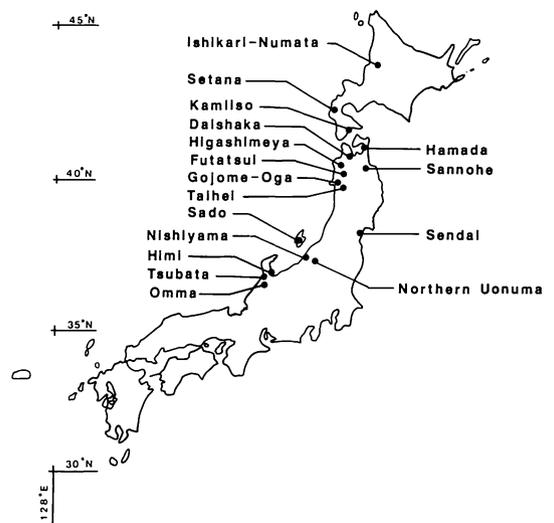
In the Neogene off-shore faunas, however, such a relationship of associations has not been sufficiently described. The aims of this paper are to recognize ecological parallel relationships among the latest Miocene to Pleistocene molluscan faunas, probably ranging from upper sublittoral to upper bathyal environments, in the cold water region of Japan, and to discuss relationships between these association groups and environments. Also, the fossil associations are compared with the living molluscan faunas around Japan. I previously recognized six molluscan associations and discussed their habitat preferences in the Pliocene-lower Pleistocene sedimentary basin in the Gojome-Oga Area, Northeast Honshu (Matsui, 1985a, b). In the present study, molluscan associations of other Neogene basins in Northeast Japan are compared with those of the Gojome-Oga Area with respect to taxonomic composition and environmental preference. The result will give us the bases to discuss historical and biogeographic changes in the molluscan faunas (Matsui, in prep.).

### Molluscan associations and their geologic setting

The uppermost Miocene to lower Pleistocene marine strata distributed in Hokkaido, Northeast Honshu and the Japan Sea coastal area of Central Honshu are composed of various siliciclastic sediments and contain abundant molluscan fossils of cold water nature. Three molluscan faunas, namely the Omma-Manganji, Tatsunokuchi and Takikawa-Honbetsu Faunas, have been distinguished in these strata on the basis of the difference of species composition (Otuka, 1939; Chinzei, 1963, 1978). They are different from each other in geographic and stratigraphic distributions and in their reconstruct-

ed environments. The Omma-Manganji Fauna appears in the uppermost Miocene to lower Pleistocene formations, and is distributed mainly in the coastal area of the Japan Sea. It is composed of deep off-shore to shallow subtidal dwellers (Kaseno and Matsuura, 1965; Chinzei, 1973; Ogasawara, 1977). The Tatsunokuchi Fauna is known from the Pliocene distributed in the Pacific coast of Northeastern Honshu, and is of an embayment environment (Chinzei and Iwasaki, 1967). It contains forms congeneric to, but different in species level from those of the Omma-Manganji Fauna, with forms characteristic to the fauna as represented by *Fortipecten*. The Takikawa-Honbetsu Fauna, which is restricted to the Pliocene of Hokkaido, is composed of both off-shore and shallow sea elements, including *Fortipecten* (Uozumi, 1962).

Composition of these molluscan faunas, stratigraphy and lithology are summarized here for six areas (Gojome-Oga; Tsubata; Omma; Sado; Hamada; Ishikari-Numata) with supplementary data from other areas (Himi; Nishiyama; Northern Uonuma; Taihei; Futatsui; Higashimeya; Daishaka;



**Figure 1.** Map of the Japanese Islands and showing the locations of the late Miocene-early Pleistocene sequences concerned in this study.

Kamiiso ; Setana ; Sannohe ; Sendai) (Figure 1). Details of these faunas were described elsewhere (Matsui, 1985a, b, c, 1988). The Pliocene and Pleistocene strata in these areas include various sedimentary types and contain well preserved molluscan fossils. Data for the supplementary areas are based on publications, and samplings made by myself.

The strata containing these molluscan faunas generally represent regressive sequence from off-shore muddy facies to near-shore sandy sediments upward. Molluscan fossils are abundant in coarser-grained facies of the later stage of the regression. Because these fossiliferous sediments appear as separate sedimentary basins, different lithostratigraphic classifications have been established for each basin, and interbasinal correlations are inevitable prior to discuss distributions of molluscan faunas in time and space. Age assignments of the sequences studied are principally based on published biostratigraphy of planktonic microfossils, in some cases combined with magnetostratigraphic records. For areas of no published age data, the ages are inferred from planktonic microfossils obtained during the present study.

The term "assemblage" used here is defined as a set of molluscs found from a bed within 20 to 100 cm thick in one small exposure. Molluscs larger than 2 mm were extracted from about 2 to 10 kg bulk-rock sample obtained from the bed, and were identified. The whole set of the molluscs are treated as an assemblage. In the Ishikari-Numata section, where exposures are nearly parallel to the bedding planes, molluscs in an exposure surface of 1 m<sup>2</sup> were collected to represent an assemblage.

Consistent and recurrent association of species is recognized among the assemblages in each area. Because most of the molluscs are considered to be autochthonous as discussed below, these faunal associations recognized may be regarded to represent a part of a past benthic community in the sense of Peter-

sen (1918, 1924).

Honda (1978) and Shimamoto (1984) proposed more split molluscan associations than those of Matsui (1985a, b) in the Gojome-Oga Area. It is, however, difficult to recognize a causal relationship between these split associations and environmental factors inferred from sedimentary facies. Moreover, splitting of associations makes inter-areal comparisons of associations difficult, because local or accidental variations of the species compositions are more likely to be overemphasized.

Preservation of original community composition in fossil associations largely depends on degree of post-mortem transportation and mixing of the living assemblages. The strata enclosing the fossil faunas are composed of various sedimentary facies, but are dominated with siltstone or fine-grained sandstone, in which many well-preserved molluscs are found. Shells show wide range in size, and many microscopic immature shells are found, particularly in the muddy sediments. Deep-burrowing bivalves such as *Mya* and *Thyasira* are usually preserved at the living position, while shells of non- or short-siphonate shallow burrowers are found as separated valves and randomly oriented. The shells of these shallow burrowers, however, are rarely abraded or broken. The difference in preservation between deep and shallow burrowers seems quite reasonable because the shells of the shallow burrowers are easily reworked and dislocated by the current or activities of burrowing organisms (Matsui, 1985a).

Fine-grained sediments occasionally intercalate aggregated shell beds, in which shells are more or less abraded and sometimes fragmented. These abraded fossils seem to have been transported after death. Ogasawara (1977) distinguished five molluscan associations in the sand-dominated Omma Formation of the Omma area in Kanazawa. These five associations seem rather complex in species composition, partly due to post-mortem transportation and mixing of species originated from different communities. In

this study, such transported assemblages are excluded from the faunal analysis.

### Brief descriptions of local associations

#### Gojome-Oga Area, Akita Prefecture

Modes of occurrence and composition of the fossil molluscan fauna in the Gojome-Oga Area were described by Matsui (1985a, b). The fauna was regarded as the Pliocene to Early Pleistocene (Matsui, 1981, 1985a). Sato *et al.* (1988), however, showed that the whole of the sequence containing the molluscan fossils should be assigned to the Pliocene on the basis of calcareous nannofossil and planktonic foraminiferal assemblages.

The fossil molluscs appear in various sedimentary facies ranging from deep turbidite to shallow fine-grained sand facies. Six molluscan associations are recognized among the fossil fauna.

The *Delectopecten* Association (= *Palliolium* Association of Matsui, 1985a) composed only of *Delectopecten peckhami* (Gabb) is restricted to deep turbidite facies. The *Nuculana* Association is characterized by nuculanid bivalves with buccinid and turrid gastropods. It appears mainly in silty facies. The *Thyasira bisecta* Association is low in diversity, predominated by *Thyasira bisecta* (Conrad). It is found from both sandy and silty facies.

The *Acila-Turritella* Association is the commonest among the molluscan associations in the area, characterized by *Acila nakazimai* Otuka, *Turritella saishuensis* Yokoyama, *Macoma calcarea* (Gmelin), *Clinocardium chikagawaense* Kotaka, *Mya cuneiformis* (Böhm) and *Glycymeris derelicta* (Yokoyama). It is found mainly in sandy silt facies.

The *Macoma tokyoensis* Association is dominated with *Macoma tokyoensis* Makiyama. The *Protothaca* Association contains thick-shelled bivalves such as *Protothaca adamsi* (Reeve) and *Anadara amacula* (Yokoyama). The last two associations

appear in fine-grained sand facies representing the shallowest environment in the area.

#### Tsubata Area, Ishikawa Prefecture

The *Acila nakazimai-Turritella saishuensis* Association is recognized in the section of 30 m thick, belonging to the Tsubata Siltstone of the Himi Formation (Sumi, 1978). The section is assigned to the uppermost Pliocene or lowest Pliocene on the basis of calcareous nannofossils (T. Takayama, personal communication). The section is composed of siltstone in the lower part and grades upward into sandy siltstone. The sand content rises from 30–35% to 50–65% upward. The sediments are intensively bioturbated and contain well preserved molluscan fossils. This association is dominated by *Acila nakazimai* and *Turritella saishuensis*, accompanied with *Clinocardium chikagawaense* in the siltstone and with more diverse molluscs such as *Limopsis* sp. A and *Cyclocardia* cf. *crebricostata* (Krause) in sandy siltstone.

#### Omama Area, Ishikawa Prefecture

Molluscan fossils were examined in the section of about 200 m thick along the Saigawa River in Kanazawa City, where the lower Pleistocene Omama Sandstone of the Himi Formation is exposed (Hasegawa, 1979; Takayama *et al.*, 1988). This section is mainly composed of well-sorted fine-grained sandstone, which is rather muddy and finer grained in the middle part. The sandstone is poor in current-generated sedimentary structures and abundantly contains mud tubes and mud pellets created by burrowing organisms.

Molluscan fossils usually occur sporadically, but several crowded shell beds are also found in the section. The shells showing the sporadic occurrence are well preserved and do not seem to have been transported from their original habitats.

The following four associations are recognized among these autochthonous molluscan fossils. The lithofacies are similar to each other, fine-grained sandstone, but each of these associations shows a characteristic species composition and occupies a distinct

stratigraphic position in the section.

*Acila insignis-Turritella saishuensis* Association: This association usually occurs as moderately diverse assemblages in the middle part of the section. It is characterized by abundant and ubiquitous occurrence of *Acila insignis* (Gould), *Turritella saishuensis*, associated with *Lunatia pila* (Pilsbry), *Searlesia japonica* Yokoyama, *Huxleyia sulcata* A. Adams, *Yoldia notabilis* Yokoyama, *Felaniella usta* (Gould), *Cyclocardia ferruginea* (Clessin), *Clinocardium fastosum* (Yokoyama) and *Pandora pulchella* Yokoyama. Some others such as *Ringicula doliaris* Gould, *Mizuhopecten tokyoensis*, and *Macoma tokyoensis* are also numerically abundant but they also appear commonly in other associations described below. At an assemblage in the muddy middle part of the section, *Acila insignis* is substituted by congeneric *A. divaricata* (Hinds). *Nucula niponica* Smith, *Cycladicama cumingii* (Hanley) and *Nemocardium samarangae* (Makiyama) exclusively appear in this assemblage in addition to *Turritella saishuensis* and *Cyclocardia ferruginea*.

Kitamura and Kondo (in press) recognized in the middle part of the Omma section, cyclic changes of molluscan composition and occurrence, which are induced primarily by glacio-eustatic sea level change. One cycle begins with a densely crowded bed of molluscan shells composed of upper sublittoral cold water species, and changes upward to autochthonous shells of transgressive lower sublittoral faunas which are usually warm water nature. The *Acila insignis-Turritella saishuensis* Association corresponds with the lower sublittoral associations of Kitamura and Kondo (in press).

*Scapharca pseudosubcrenata* Association: This association is highly diverse and appears in a 4 m-thick interval at the uppermost part of the section. Two large bivalve species of *Scapharca*, *S. aff. ommaensis* (Otuka) and *S. pseudosubcrenata* (Ogasawara), are characteristic in the association, though they are not

numerous. Smaller species such as *Reti-cunassa* sp., *Oliva mustelina* Lamarck, *Pil-lucina yamakawai* (Yokoyama), and *Ver-emolpa minuta* (Yokoyama) also characterize the association and occur abundantly. Some others such as *Mitrella lischkei* (Smith), *Ringicula doliaris* Gould, *Saccella confusa* (Hanley), and *Pecten albicans* (Schröter) are also abundant but they also appear in the *Acila insignis-Turritella saishuensis* Association.

*Scapharca ommaensis* Association: This association is characterized by abundant *Scapharca ommaensis* (Otuka). Conjoined individuals of the species are accompanied with a smaller number of well-preserved, separated shells of *Mizuhopecten tokyoensis* (Tokunaga) and *M. yokoyamae* (Masuda). *Scapharca ommaensis* is very akin to *S. aff. ommaensis*, which characterizes the *S. pseudosubcrenata* Association. But the present association is different from the preceding one in the species composition other than *Scapharca* and in having lower species diversity. The association occurs at a lower horizon of the section, stratigraphically about 100 m below the *S. pseudosubcrenata* Association.

*Anadara amacula* Association: This association is characterized by abundant *Anadara amacula* and *Clinocardium* sp., associated with *Turritella saishuensis*, *Striodentalium rhabdotum* (Pilsbry) and isolated immature shells of two pectinid species, *Mizuhopecten yokoyamae* and *M. tokyoensis*. This association occupies the lowest horizon of the section, about 40 m below the *Scapharca ommaensis* Association.

Sado Area, Niigata Prefecture

Two lower Pleistocene fossil localities were examined in Sado Island.

*Nuculana* Association: This association is observed in sparsely bedded, dark-greenish-gray coarse-grained siltstone of the Shichiba Formation (Utashiro *et al.*, 1977) at a large seaside exposure of Shichiba. It is mainly composed of two deposit-feeding bivalves of *Nuculana robai* (Kuroda) and *Portlandia*

*toyamaensis* (Kuroda) associated with *Axinopsida subquadrata* (A. Adams) and *Siphonodentalium* sp. The shells are sporadically dispersed in the siltstone, and minute unidentified gastropods and bivalves are abundant.

Transported assemblages: Three assemblages from calcareous medium- to coarse-grained sandstone belonging to the Kaidate Formation (Utashiro *et al.*, 1977) at Kaidate seem to have been experienced post-mortem transportation and accumulation, for the shells are crowded and many of them are abraded and broken. They are characterized by abundance of the pectinid species such as *Chlamys cosibensis* (Yokoyama). *Glycymeris* sp. and some other epifaunal or shallow burrowing bivalves are also common. Although these assemblages were transported after death, they are similar to some non-transported assemblages in coarse sediments as discussed later. They probably preserve a part of their original composition of the living community.

#### Hamada Area, Aomori Prefecture

The section belonging to the Hamada Formation (Yamaguchi, 1970; Kanazawa and Yamaguchi, 1988) exposed along the Chikagawa River, north of Hamada is examined, supplemented by exposures along the Maekawa River. This section is composed of tuffaceous, calcareous, medium- to coarse-grained sandstone in the lower part, and fine-grained sandstone and massive siltstone in the upper part. The section is assigned presumably to the lower Pleistocene on the basis of planktonic foraminifers (H. Kitazato, personal communication). Well-preserved molluscs of eight assemblages are grouped into the following two associations.

*Acila-Macoma* Association: This association appears both in the siltstone and fine-grained sandstone of the upper part of the section. *Acila nakazimai*, *Macoma calcarea* and *Clinocardium chikagawaense* are dominant. The assemblages in the silty part are associated with *Mya cuneiformis*, *Portlandia*

sp. and *Thyasira bisecta*. The assemblages in the fine-grained sandstone contain more diverse species, among which *Turritella saishuensis*, *Nuculana yokoyamai* Kuroda and *Cyclocardia ferruginea* are numerous.

*Chlamys* Association: Some pectinid species such as *Chlamys cosibensis*, *C. islandica* (Müller), *Yabepecten tokunagai* (Yokoyama) and *Polynemamussium alaskense* (Dall) are characteristic of this association. *Cyclocardia ferruginea*, *Tridonta alaskensis* (Dall) and some others are commonly found in this association, but they also appear in the *Acila-Macoma* Association. This association occurs in the lower calcareous medium- to coarse-grained sandstone.

#### Ishikari-Numata Area, Hokkaido

The molluscan associations in this area were described elsewhere (Matsui, 1988). A brief summary of the associations is as follows.

The Pliocene Horokaoshirarika Formation (Kobayashi *et al.*, 1969) is exposed along the Horonitachibetsu River, northwest of Ishikari-Numata.

*Anadara* Association: This association is characterized by abundant *Anadara amacula* associated with *Clinocardium* sp., *Protothaca adamsi* and *Felaniella usta*. *Fortipecten takahashii* (Yokoyama) and *Macoma calcarea* are also numerous. This association mainly appears in the upper sandstone part of the section.

*Acila nakazimai-Turritella fortilirata* Association: This association is characterized by *Acila nakazimai* and *Turritella fortilirata* Sowerby associated with *Lucinoma acutilineata* (Conrad), *Cyclocardia* sp. and *Mya cuneiformis*. *Fortipecten takahashii* and *Macoma calcarea* are abundant but not characteristic of the association. This association appears in the lower alternation part of the section.

Table 1. Representative species of the seven association groups.

Association Group	D	Nuculana				Acila-Turritella				Anadara				MM	Th	Ch				
		GO	SD	GO	FU	TS	OM	GO	FU	HA	IS	GO	FU	GO	IS	OM	OM	SE	GO	HA
<i>Delectopecten peckhami</i>	●				•															
<i>Lunatia pallida</i>		○	•	•	•															
<i>Fusitriton oregonensis</i>			•	•	•															
<i>Buccinum cf. rossicum</i>			○	○	○															
<i>Mohnia cf. yanamii</i>			○	○	○															
<i>Neptunea intersculpta</i>			•	•	•															
<i>Antiplanes sanctiloanis</i>			•	•	•															
<i>Nuculana robai</i>		●	○	○	○															
<i>Portlandia toyamaensis</i>		●	•	•	•															
<i>Buccinum spp.</i>			•	•	•															
<i>Propebela candida</i>			○	○	○															
<i>Portlandia hirosakiensis</i>			•	•	•	○														
<i>Cryptonatica clausa</i>			○	○	○								•	○						
<i>Neptunea spp.</i>			•	•	•															
<i>Turritella nipponica</i>			•	•	•															
<i>Nuculana yokoyamai</i>			•	•	•															
<i>Yoldia thraciaeformis</i>			•	•	•	○														
<i>Clinocardium chikagawaense</i>			•	•	•	○														
<i>Macoma calcarea</i>			○	○	○															
<i>Acila nakazimai</i>			•	•	•	○														
<i>Cyclocardia ferruginea</i>			•	•	•	○														
<i>Limopsis tokaiensis</i>			•	•	•															
<i>Turritella fortilirata</i>			•	•	•															
<i>Limopsis sp.A</i>			•	•	•															
<i>Acila insignis</i>			•	•	•															
<i>Fortipecten takahashii</i>			•	•	•															
<i>Mya cuneiformis</i>			•	•	•															
<i>Turritella saishuensis</i>			•	•	•	○														
<i>Macoma tokyoensis</i>			•	•	•															
<i>Glycymeris yessoensis</i>			•	•	•															
<i>Anadara amicula</i>			•	•	•															
<i>Scapharca ommaensis</i>			•	•	•															
<i>Scapharca pseudosubcrenata</i>			•	•	•															
<i>Scapharca aff. ommaensis</i>			•	•	•															
<i>Dosinia tomikawensis</i>			•	•	•															
<i>Mercenaria stimpsoni</i>			•	•	•															
<i>Protothaca adamsi</i>			•	•	•															
<i>Clinocardium sp.</i>			•	•	•															
<i>Mya japonica</i>			•	•	•															
<i>Lucinoma annulata</i>			•	•	•															
<i>Lucinoma acutilineata</i>			•	•	•															
<i>Thyasira bisecta</i>			•	○	○															
<i>Chlamys cosibensis</i>			•	•	•															
<i>Chlamys islandica</i>			•	•	•															
<i>Polynemamussium alaskense</i>			•	•	•															
<i>Yabepecten tokunagai</i>			•	•	•															

Association groups: *D* = *Delectopecten*; *MM* = *Macoma-Mya*; *Th* = *Thyasira*; *Ch* = *Chlamys*. Area: FU = Futatsui; GO = Gojome-Oga; HA = Hamada; IS = Ishikari-Numata; OM = Omma; SD = Sado; SE = Sendai; TS = Tsubata. Symbols indicate relative abundance (● < ○ < ●).

### Types of molluscan associations and their relationship with environments

The fifteen recurrent molluscan associations described above are recognized primarily on the basis of taxonomic composition. Each of them is found in a particular sediment type and in the particular stratigraphic and geographic positions of the sedimentary basin. The lithofacies in which molluscs were found range from siltstone to coarse-grained sandstone.

These fifteen local associations are grouped into seven types of associations, here called the association groups, on the basis of similarity in the species or genus composition. For example, the local *Nuculana* Associations in the Gojome-Oga and Sado and the *Nuculana-Turritella nipponica* Association in the Futatsui are abundant in *Nuculana robai* and other nuculanid bivalves with buccinid gastropods. These three local associations are grouped into one association group, the *Nuculana* Association Group. Seven association groups are recognized in the same manner in the areas studied: namely *Delectopecten*, *Nuculana*, *Acila-Turritella*, *Anadara*, *Mya-Macoma*, *Thyasira* and *Chlamys* Association Groups. The local associations belonging to an association group are found from the same sediment type in the same stratigraphic and geographic positions of the different sedimentary basins, and hence these associations seem closely related to a particular environment, regardless of age and biogeographic province of individual associations. In this sense, the local associations included in one association group are in an ecological parallel relationship, though Thorson (1957) originally used "ecological parallelism" confined to contemporaneous communities which are biogeographically isolated.

Relationships between the associations and environments have been discussed in the Futatsui and Gojome-Oga, where five of these association groups are recognized (Chinzei, 1973; Matsui, 1985a). Sediment type and

water depth were concluded to be the essential factors governing the distribution of the associations in the areas. The similar relationships between molluscan associations and lithofacies are observed in other latest Miocene to early Pleistocene basins in Northeast Japan, though geographic and stratigraphic distributions of the associations in these basins have not been fully described. The association groups are comparable with living molluscan faunas of the continental shelves and slopes around Japan in composition and in relationship with environment.

The association groups and their living analogues can be utilized for comparison among faunas within a certain habitat but in different ages and different biogeographic provinces, because of its consistency in environmental relationship as well as taxonomic composition.

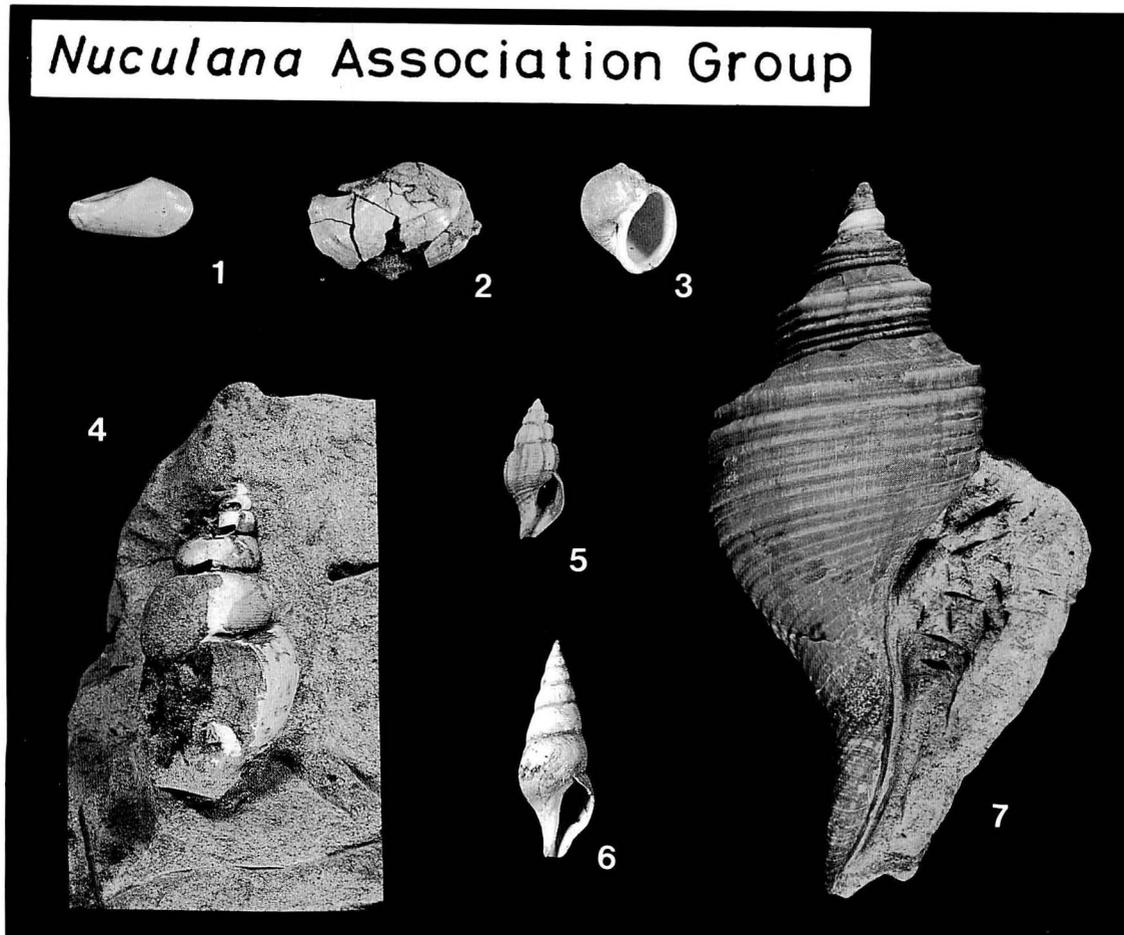
The characters in the species composition of the seven groups and their relation to environments are summarized as follows and illustrated in Table 1 and Figures 2-6.

#### *Delectopecten* Association Group

This group is typically found in mudstone of the turbidite sequence in the Gojome-Oga as the *Delectopecten* Association, which is composed exclusively of *Delectopecten peckhami*. The association may have occupied the deepest environment among the associations found. The siliceous mudstone of the Funakawa Formation in the Gojome-Oga probably represents more off-shore facies, but is barren of molluscs.

This small and thin pectinid species commonly occurs as monospecific assemblage in the Miocene-early Pleistocene offshore muddy sediments in Northeast Japan (Uta-shiro, 1957). This association group represents the deepest biofacies in the area studied. *Delectopecten peckhami* is an extinct species. Similar thin-shelled pectinid species, however, commonly appear in present-day continental slopes. *Delectopecten macrocheiricola* Habe and many other species of fragile pectinid are found from muddy bottom of 500

## Nuculana Association Group



**Figure 2.** Major faunal elements of the *Nuculana* Association Group. **1**, *Nuculana robai* (Kuroda), Sado Area, Shichiba Formation,  $\times 1$ ; **2**, *Portlandia toyamaensis* (Kuroda), Sado Area, Shichiba Formation,  $\times 1$ ; **3**, *Lunatia pallida* (Broderip and Sowerby), Sado Area, Shichiba Formation,  $\times 1$ ; **4**, *Buccinum* sp., Taihei Area, Tentokuji Formation,  $\times 1$ ; **5**, *Mohnia* cf. *yanamii* (Yokoyama), Gojome-Oga Area, Wakimoto Formation,  $\times 1$ ; **6**, *Antiplanes sanctiioannis* (Smith), Gojome-Oga Area, Wakimoto Formation,  $\times 1$ ; **7**, *Neptunea intersculpta* (Sowerby), Taihei Area, Tentokuji Formation,  $\times 0.9$ .

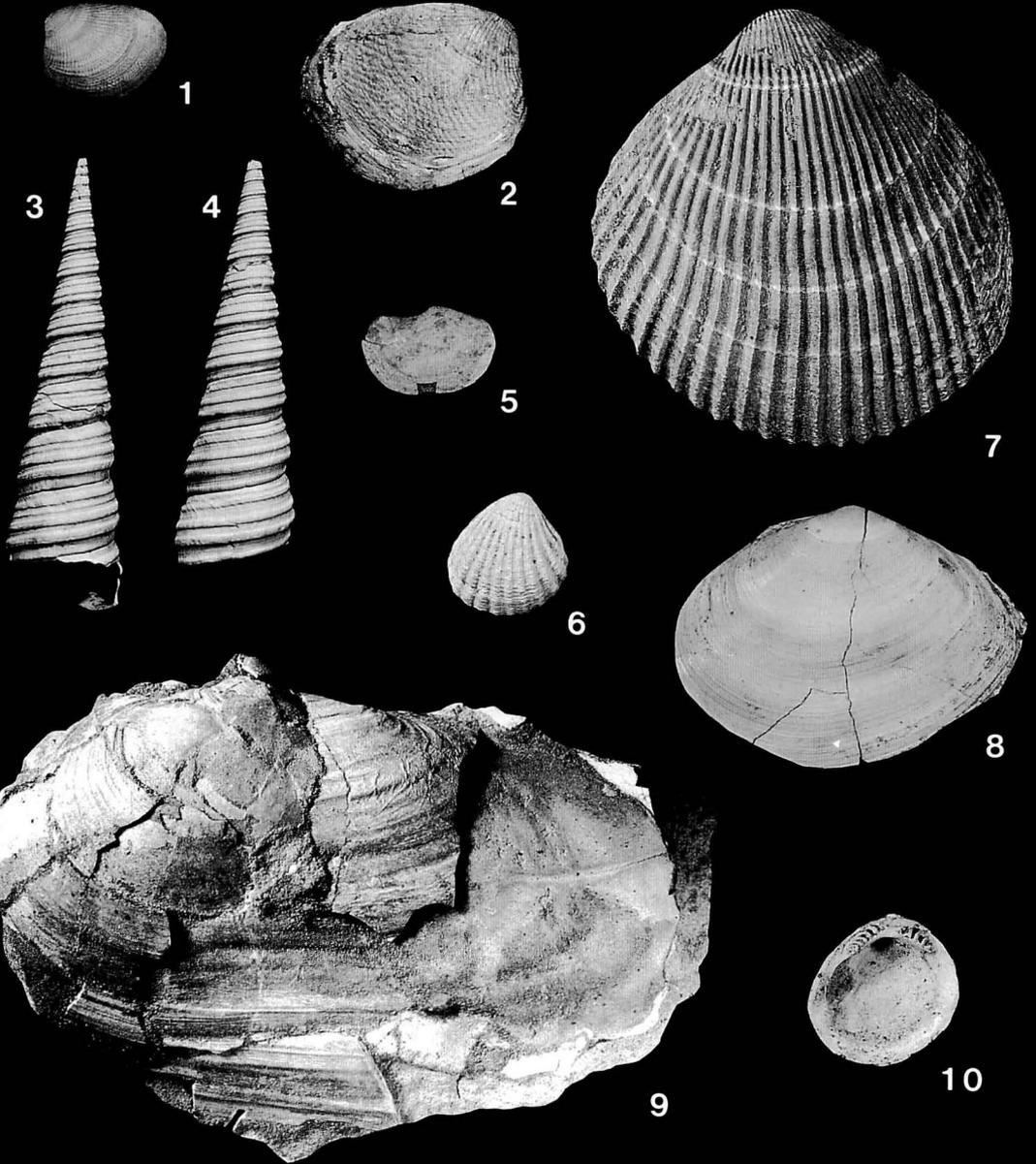
to 2,000 m deep in the Pacific coastal areas of Japan (Okutani, 1962).

*Nuculana* Association Group (Figure 2)

This type of association is represented by the *Nuculana* Association of the Sado and Gojome-Oga and the *Nuculana-Turritella nipponica* Association of the Futatsui, appearing in muddy facies. This is dominated by small deposit-feeding nuculanid and nuculid bivalves and carnivorous or saprophagous gastropods. Among them, *Nuculana robai* is the most common and widely

distributed species. Other nuculanids and nuculids such as *Portlandia toyamaensis*, *P. hirosakiensis* Iwai, *Saccella onoyamai* (Otuka) and *Acila nakazimai* are locally abundant. The gastropods are represented by many buccinid, turrid and naticid species, among which *Mohnia yanamii* (Yokoyama), *Antiplanes sanctiioannis* (Smith), *Propebela candida* (Yokoyama) and *Lunatia pallida* (Broderip and Sowerby) are common, occasionally associated with *Neptunea intersculpta* (Sowerby), *Buccinum* cf. *rossicum*

# Acila - Turritella Association Group



Dall, *B. tsubai* Kuroda and cymatiid *Fusitrito oregonensis* (Redfield). Some bivalves such as *Limopsis tokaiensis*, *Macoma calcarea* and *Thyasira bisecta* occasionally appear in the associations.

Fossil assemblages comparable to these associations have been reported rather rarely, probably owing to very low density of individuals in the sediments. Many nuculanid species were found in muddy facies of the Nishiyama Formation in the Northern Uonuma (Itoigawa, 1958). Four assemblages from the late Miocene Shitazaki Siltstone and Kamassawa Alternation in the Sannohe contain *Nuculana robai* and *N. pernula* (Müller) (Chinzei, 1979). A nuculanid and buccinid fauna is found from siltstone and sandy siltstone of the Pliocene Tentokuji Formation in the Taihei Area, the fauna composed of *Nuculana robai*, *Neptunea intersculpta*, *Buccinum* spp. and *Fulgoraria prevostiana* (Matsui, 1977 MS).

This association group is known in the Gojome-Oga basin from deep and muddy environments but shallower than the *Delectopecten* Association (Matsui, 1985a).

Living molluscan faunas analogous to the *Nuculana* Association Group are found in the muddy upper bathyal zone. A low diversity bathyal fauna comparable in species composition with the fossil *Nuculana* Association Group was found from two silty stations of about 200 m deep off the Oga Peninsula (Takayasu and Yunohara, 1977). This fauna is dominated by small deposit-feeders of *Nuculana pernula*, *N. robai* and *Yoldia amygdalea* (Valenciennes). In the area off Kushiro, deposit feeding bivalves of *Malletia* aff. *takaii* (Okutani) and *Nuculana* cf. *sagamiensis* Okutani appear on silt bottom

deeper than 900 m (Matsui, 1985c).

A diverse molluscan fauna is living in muddy continental slope of 200–1,500 m deep in Sagami Bay under the influence of the lower temperature “intermediate water” beneath the warm Kuroshio water (Horikoshi, 1957; Okutani, 1968). This living fauna contains many genera common to the fossil *Nuculana* Association Group, such as *Nuculana*, *Limopsis* and *Neptunea*, though they are different in species level. In addition to these, the living upper bathyal fauna is rich in genera but rare or absent in the fossil *Nuculana* Association. For example, cuspidariid bivalves and trochid gastropods are very rare in the fossils.

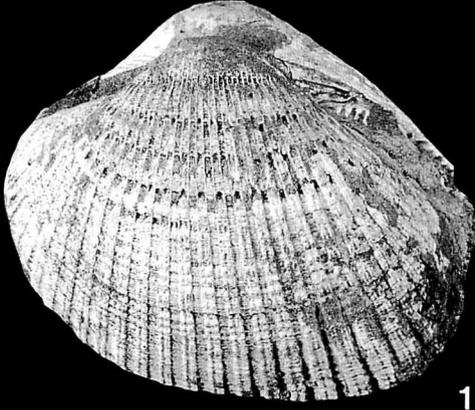
*Acila-Turritella* Association Group (Figure 3)

This is the commonest type of associations in the Omma-Manganji and Takikawa-Honbetsu Faunas. The *Acila-Turritella* Association in the Gojome-Oga is typical of this group. The local associations included in this group are present in all the basins examined, and appear in sandy siltstone or fine-grained sandstone. The characteristic common constituents of these associations are species of *Acila* (*A. nakazimai*, *A. insignis*, *A. divaricata*) and *Turritella* (*T. saishuensis*, *T. fortilirata*, *T. fortilirata habei* Kotaka). They are commonly associated with *Macoma calcarea*, *Clinocardium chikagawaense*, *Cyclocardia ferruginea*, *Mya cuneiformis*, *Glycymeris derelicta* and some others.

Among these species of *Acila*, an extinct *A. nakazimai* is most prevalent and widely distributed. *Acila divaricata* is rather rare. This species is associated with *Acila nakazimai* in the Kamiiso (Sakagami *et al.*, 1966). The Omma section contains both *A. insignis*

← **Figure 3.** Major faunal elements of the *Acila-Turritella* Association Group. 1, *Acila insignis* (Gould), Omma Area, Omma Sandstone; 2, *Acila nakazimai* Otuka, Gojome-Oga Area, Sasaoka Formation; 3, 4, *Turritella saishuensis* Yokoyama, (3, typical specimen; 4, *habei* type specimen. See text for further explanation), Hamada Area, Hamada Formation; 5, *Yoldia thraciaeformis* (Störer), Tsubata Area, Tsubata Siltstone; 6, *Cyclocardia ferruginea* (Clessin), Futatsui Area, Sasaoka Formation; 7, *Clinocardium chikagawaense* Kotaka, Hamada Area, Hamada Formation; 8, *Macoma calcarea* (Gmelin), Hamada Area, Hamada Formation; 9, *Mya cuneiformis* (Böhm), Gojome-Oga Area, Sasaoka Formation; 10, *Limopsis tokaiensis* Yokoyama, Futatsui Area, Sasaoka Formation. All in natural size.

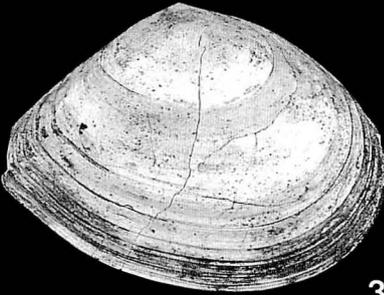
**Anadara Association Group**



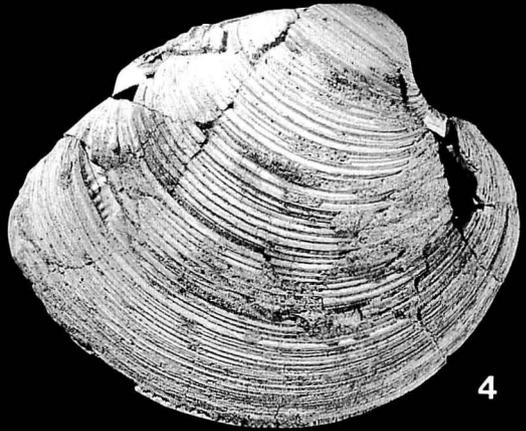
1



2



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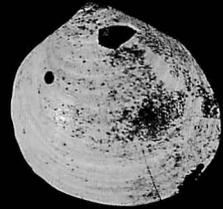
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7

and *A. divaricata*, which do not coexist with each other, as noted before.

Species of *Turritella* also differ in places. The three species of *Turritella* rarely exist with one another in a local association, and show different stratigraphic and geographic distributions. *Turritella saishuensis* is restricted to the Pliocene—early Pleistocene Japan Sea side of Honshu. *Turritella fortilirata* appears in the Pliocene Takikawa-Honbetsu Fauna of central Hokkaido. *Turritella* in the lower Pleistocene of southwestern Hokkaido was assigned to a subspecies of *T. fortilirata* (*T. f. habei*) (Kotaka, 1959; Kanno, 1962; Sakagami *et al.*, 1966). In the transitional area between the realms of *T. saishuensis* and *T. f. habei* at the northern end of Honshu, there are populations intermediate between these two species. The population of *Turritella* in some assemblages of the Hamada Formation includes both of *saishuensis* and *habei* type specimens in respect to spiral ornamentation (Figures 3–3, 4), as well as intermediate forms between the two types in the same assemblage. Similar intermediate populations were reported from sandy siltstone of the Higashimeya Formation in the Higashimeya (Iwai, 1965). The name of *saishuensis* is tentatively applied to these populations.

Other constituent species of the associations are in some extent different from area to area. The difference is partly due to difference in lithology or stratigraphic horizon and partly to difference in geographic position of the sections. *Cyclocardia* spp., *Mya cuneiformis* and *Macoma calcarea* are found commonly in the sand-dominated Omma, Futatsui and Ishikari-Numata sections and in sandy parts of other sections. *Clinocardium chikagawaense*, *Yoldia thraciaeformis* (Stor-

er), *Portlandia hirosakiensis* are prevalent in the muddy sections of the Tsubata, Gojome-Oga and Hamada. *Limopsis* is represented by *L. tokaiensis* Yokoyama in the sandy section of the Futatsui, while by *L. sp.* A (an akin form of *L. tokaiensis*) in the muddy Tsubata section.

The species common to this association group are found in siltstone and fine-grained sandstone of the Haizume Formation in the Northern Uonuma (Itoigawa, 1958). Three assemblages from fine-grained sandstone of the late Miocene Kamassawa Alternation in the Sannohe (Chinzei, 1959) are dominated by the representative species or their close relatives of this association group such as *Cyclocardia ochiaiensis* (Chinzei) (akin to *C. ferruginea*), *Clinocardium iwataense* Chinzei (very similar to *C. chikagawaense*), *Macoma calcarea* and *Glycymeris derelicta*, and also contain a few species common to the *Nuculana* Association Group.

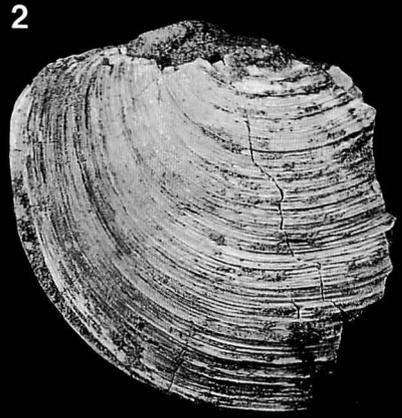
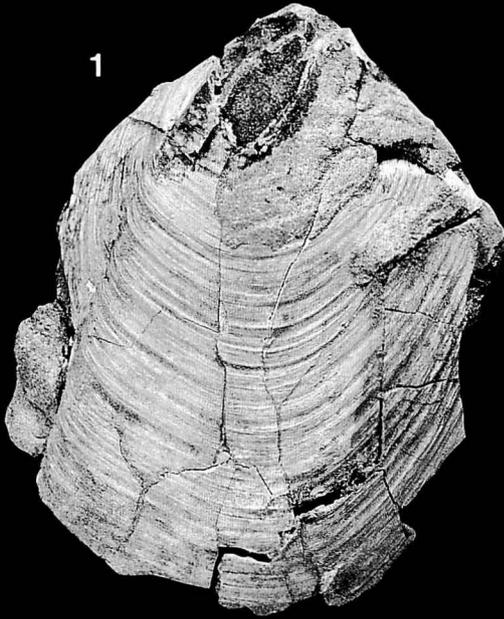
In the regressive sequences of the Futatsui, Gojome-Oga and Northern Uonuma, the associations included in this group appear in sandy silt facies or fine-grained sand facies, and occupy stratigraphic levels upper than those of the *Nuculana* Association Group (Itoigawa, 1958; Chinzei, 1973; Matsui, 1985a). This suggests that the *Acila-Turritella* Association Group was the dweller shallower than the *Nuculana* Association Group. In the Futatsui and Gojome-Oga, the *Turritella-Limopsis-Acila* and *Acila-Turritella* Associations are found in the areas presumably nearer to the coast than those of the *Nuculana-Turritella nipponica* and *Nuculana* Associations (Chinzei, 1973; Matsui, 1985a). This supports the above inference.

Many of the main constituent species of the

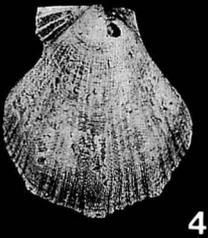
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← **Figure 4.** Major faunal elements of the *Anadara* Association Group. **1**, *Anadara amicola* (Yokoyama), Ishikari-Numata, Horokaoshirarika Formation; **2**, *Scapharca* aff. *ommaensis* (Otuka), Omma Area, Omma Sandstone; **3**, *Macoma tokyoensis* Makiyama, Omma Area, Omma Sandstone; **4**, *Mercenaria simpsoni* (Gould), Gojome-Oga Area, Sasaoka Formation; **5**, *Protothaca adamsi* (Reeve), Gojome-Oga Area, Sasaoka Formation; **6**, *Glycymeris yessoensis* (Sowerby), Omma Area, Omma Sandstone; **7**, *Felaniella usta* (Gould), Omma Area, Omma Sandstone. All in natural size.

**Thyasira Association Group**



**Chlamys Ass. Group**



*Acila-Turritella* Association Group have been extinct. However, congeneric species of these extinct forms are living lower sublittoral zone.

The lower sublittoral fauna off Kushiro in eastern Hokkaido (Matsui, 1985c) is predominated by cold water species. *Macoma calcarea* and *Turritella fortilirata* of this fauna are the species common to the fossil *Acila-Turritella* Association. *Clinocardium ciliatum* (Fabricius) living in this fauna is closely related with *Clinocardium chikagawaense* in the fossil association.

The muddy lower shelf fauna of about 40 to 200 m deep in Sagami Bay is composed of bivalves of *Glycymeris rotunda*, *Venus foveolata* Sowerby, *Acila divaricata*, *Angulus vestalioides* (Yokoyama) and various gastropod species (Horikoshi, 1957). The fauna is living in the warm water. Among them, *G. rotunda* and *A. divaricata* appear in the fossil *Acila-Turritella* Association in the Omma.

*Anadara* Association Group (Figure 4)

Local associations included in this group are found in fine-grained sandstone. They are characterized by common occurrences of *Anadara amacula* or *Scapharca* spp., associated with large suspension-feeding bivalves of *Dosinia tomikawensis* Takagi, *Mercenaria stimpsoni* (Gould), *Protothaca adamsi* and deep-burrowing *Macoma tokyoensis*. *Turritella saishuensis* and *Macoma calcarea* are also found in these associations.

The *Protothaca* Association of the Gojome-Oga and the *Anadara* Association of the Ishikari-Numata are representatives of this group of associations. *Anadara amacula*, *Mercenaria stimpsoni*, *Protothaca adamsi* and *Macoma calcarea* are common in these two associations, and the association in the Ishikari-Numata accompanied with *For-*

*tipecten takahashii*.

The *Macoma tokyoensis* Association of the Gojome-Oga and the *Turritella saishuensis-Macoma tokyoensis-Mercenaria* Association of the Futatsui are dominated by *Macoma tokyoensis* and *Turritella saishuensis*, containing *Anadara* and *Mercenaria* as subordinate elements.

Two associations characterized not by *Anadara* but *Scapharca* species appear in the Omma. The *Scapharca pseudosubcrenata* Association contains *S. pseudosubcrenata*, *S. aff. ommaensis* and *Macoma tokyoensis*, not associated with other large suspension-feeding bivalves. The *Scapharca ommaensis* Association is known from only one locality of the same area. At this locality *S. ommaensis* is very abundant and represents a distinct molluscan association.

The *Pseudamiantis-Anadara* Association in the Pliocene Sendai basin is dominated by *Pseudamiantis sendaicus* (Nomura), *Anadara tatunokutiensis* (Nomura and Hatai), *Dosinia tatunokutiensis* (Nomura) and *Fortipecten takahashii*, found in poorly-sorted, medium- to coarse-grained sandstone (Chinzei and Iwasaki, 1967). The similar association found from poorly-sorted, fine- to coarse-grained sandstone, in the Pliocene Sannohe basin (Chinzei, 1961), is composed of *Anadara tatunokutiensis nagawensis* Chinzei, *Dosinia tomikawensis*, *Mercenaria stimpsoni*, *Fortipecten kenyoshiensis* (Chinzei) and some others. These two associations represent this association group in the Tatsunokuchi Fauna.

The *Anadara* Association Group represents the shallowest environment among others. This is found from the sandy sediments of the last stage of regressive marine sequences in the Futatsui and Gojome-Oga (Chinzei, 1973; Matsui, 1985a). The *Ana-*

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← **Figure 5.** Major faunal elements of the *Thyasira* and *Chlamys* Association Groups. **1**, *Thyasira bisecta* (Conrad), Taihei Area, Tentokuji Formation; **2**, *Lucinoma acutilineata* (Conrad), Taihei Area, Tentokuji Formation; **3**, *Tridonta alaskensis* (Dall), Hamada Area, Hamada Formation; **4**, *Chlamys cosibensis* (Yokoyama), Hamada Area, Hamada Formation; **5**, *Yabepecten tokunagai* (Yokoyama), Hamada Area, Hamada Formation. All in natural size.

*dara* Association in the Ishikari-Numata occurs at the top horizon of marine sediments, dominated with sand and covered with peat-bearing non-marine sediments. The *Pseudamiantis-Anadara* Association in the Sendai basin is found in a marginal sandy area of the basin (Chinzei and Iwasaki, 1967).

The *Anadara* Association Group is analogous to the living upper sublittoral fauna of sandy substrata shallower than about 40 m (Chinzei and Iwasaki, 1967). The living fauna contains many species common to the fossil associations. Large and thick-shelled suspension-feeding bivalves of *Dosinia japonica* (Reeve), *Protothaca adamsi* and *Mercenaria stimpsoni* are commonly found in the upper sublittoral fauna of Sendai Bay (Masuda *et al.*, 1983). *Scapharca broughtonii* (Schrenck) and *S. subcrenata* (Lischke) are living representatives of Anadarinae in the place of *Anadara amacula* of the fossil associations.

The cold water fauna of the upper sublittoral zone off Kushiro is found from rocky or fine- to coarse-grained sandy bottom shallower than 30 m deep. Common species of this fauna are *Clinocardium nuttallii* (Conrad), *Protothaca adamsi*, *Mercenaria stimpsoni*, *Glycymeris yessoensis* (Sowerby), *Macoma calcarea* and *Felaniella usta* (Matsui, 1985c; Habe, 1955). These species are accompanied by large buccinid whelks such as *Buccinum middendorffi* Verkrusen and *Neptunea arthritica* (Bernardi).

The sandy fauna of the upper sublittoral zone in Sagami Bay (Horikoshi, 1957) contains species congeneric to those in the fossil *Anadara* Association Group, such as *Glycymeris albolineata* (Lischke) and *Dosinia japonica* (Reeve). This living fauna, however, lacks cold water species such as *Protothaca adamsi* and *Mercenaria stimpsoni*. Species of Anadarinae of this fauna is *Scapharca satowi* (Dunker).

#### *Macoma-Mya* Association Group

The *Macoma-Mya* Association, which appears in the central silty part of the Sendai

basin, may represent another association group lived in the shallow muddy bottom adjoining to the sandy habitat of the *Anadara* Association. This association is composed of *Macoma tokyoensis*, *Mya japonica* Jay and *Lucinoma annulata* (Reeve), which sporadically occur in the dark-gray massive silt (Chinzei and Iwasaki, 1967).

Living fauna comparable with the fossil *Macoma-Mya* Association is found in the upper sublittoral zone of muddy bottoms (Chinzei and Iwasaki, 1967).

#### *Thyasira* Association Group (Figure 5)

This is typically found in the Gojome-Oga and Taihei Areas as the *Thyasira bisecta* Association (Matsui, 1977 MS, 1985a). This association is peculiar in species composition and mode of occurrence as described by Matsui (1985a) in detail. The association is mainly composed of lucinacean bivalves, *Thyasira bisecta* with less abundant *Lucinoma acutilineata*, occasionally accompanied with *Acharax tokunagai* (Yokoyama), *Acila nakazimai* and some others as rare components. The two dominant species are usually found conjoined in standing position. Since this association often occurs stratigraphically close to the *Nuculana* Association and sometimes to the *Acila-Turritella* Association in the Gojome-Oga and Taihei, the *Thyasira* Association had a depth preference similar to the *Nuculana* Association and presumably extended up to a deeper part of the habitat of the *Acila-Turritella* Association. The *Thyasira* Association, however, has wider tolerance for sediment types than the *Nuculana* Association. It occurs in muddy, sandy and pebbly sediments (Matsui, 1985a). In the Futatsui, *Thyasira* occurs in the muddy and sandy associations as a rare element, but no assemblage composed dominantly of *Thyasira* and *Lucinoma* has been known (Chinzei, 1973). This weak relationship between the *Thyasira* Association and sediment type exhibits a contrast with the confinement of the other association groups to the particular sediment types.

Lucinacean bivalves including the genera *Thyasira* and *Lucinoma* as well as solemyid bivalves have symbiotic sulfide oxidizing bacteria in their gills (e.g., Reid and Brand, 1986). The nutritional dependence on the symbiotic bacteria and other anatomical features (Allen, 1958) indicate that these bivalves adapt to oxygen-deficient, sulfide-rich sediments, which are not suitable for other ordinary benthic animals. The distribution of the *Thyasira* Association may be controlled mainly by the reducing environments rather than grain size of sediments or hydrodynamic condition.

*Thyasira bisecta* is known from the upper bathyal zone around Japan (Kanno, 1971). The species is very rarely collected from the present sea bottoms in spite of the ubiquitous occurrence of the fossils, probably owing to the deep-burrowing habit.

*Chlamys* Association Group (Figure 5)

This is represented by the *Chlamys* Association of the Hamada. As noted in the description of the Hamada Area, some pectinid species and other epifaunal or shallow-burrowing bivalves characterize this association. Some assemblages from granule-bearing sandstone and siltstone in the Pliocene-Pleistocene Daishaka Formation of the Daishaka are rich in the species of the *Chlamys* Association such as *Chlamys* spp., *Polynemamussium alaskense*, *Cyclocardia ferruginea* and *Tridonta alaskensis* (Tabuki, 1983).

Some representative species of the *Chlamys* Association such as *Cyclocardia ferruginea* and *Polynemamussium alaskense* appear in the sandy assemblage of the *Acila-Macoma* Association in the Hamada. Similar intermediate assemblages between the *Chlamys* and *Acila-Turritella* Association Groups have been found in the Daishaka (Tabuki, 1983). The *Chlamys* Association Group occasionally contains the characteristic constituents of the *Nuculana* Association Group such as *Neptunea* spp. and *Nuculana robai*. These suggest that the *Chlamys* Association Group

is preferred water depth similar to, but coarser substrate than the *Acila-Turritella* Association Group and presumably extended to deep, but coarse-grained sand bottoms adjoining to the muddy habitat of the *Nuculana* Association Group.

The transported assemblages of the Sado Area contain many characteristic species of the *Chlamys* Association such as *Chlamys cosibensis* and *Yabepecten tokunagai*. Other constituents of the assemblages are small gastropods and byssally attaching epifaunal bivalves, which prefer coarse-grained bottoms. This implies that these transported assemblages rarely include elements derived from other biotopes. Such transported assemblages dominated by pectinid bivalves are common in the Pliocene—lower Pleistocene in Northeast Japan; for example, the Haizume Formation in the Nishiyama (Kanehara, 1950) and the Simazaki Shell Bed in the Himi (Otuka, 1935).

The living coarse-grained bottom faunas in the lower sublittoral and upper bathyal zones are different from the muddy bottom faunas of the same zones, composed mainly of *Chlamys* and other epifaunal species, comparable to the fossil *Chlamys* Association Group. *Cryptopecten vesiculosus* (Dunker), *Neopycnodonte musashiana* (Yokoyama), *Xenophora pallidula* (Reeve) are common on the sandy to gravelly lower shelf of Sagami Bay (Horikoshi, 1957). *Chlamys islandica* and other epifaunal animals such as bryozoans are living in the lower shelf off Kushiro on medium-grained sandy bottom with boulders (Matsui, 1985c). The upper bathyal fauna is mainly composed of *Chlamys islandica*, *Polynemamussium alaskense*, various species of buccinid and turrid gastropods (Matsui, 1985c). *Polynemamussium alaskense* is abundantly found on the steepest part of the upper slope between 150 to 200 m deep just below the shelf edge.

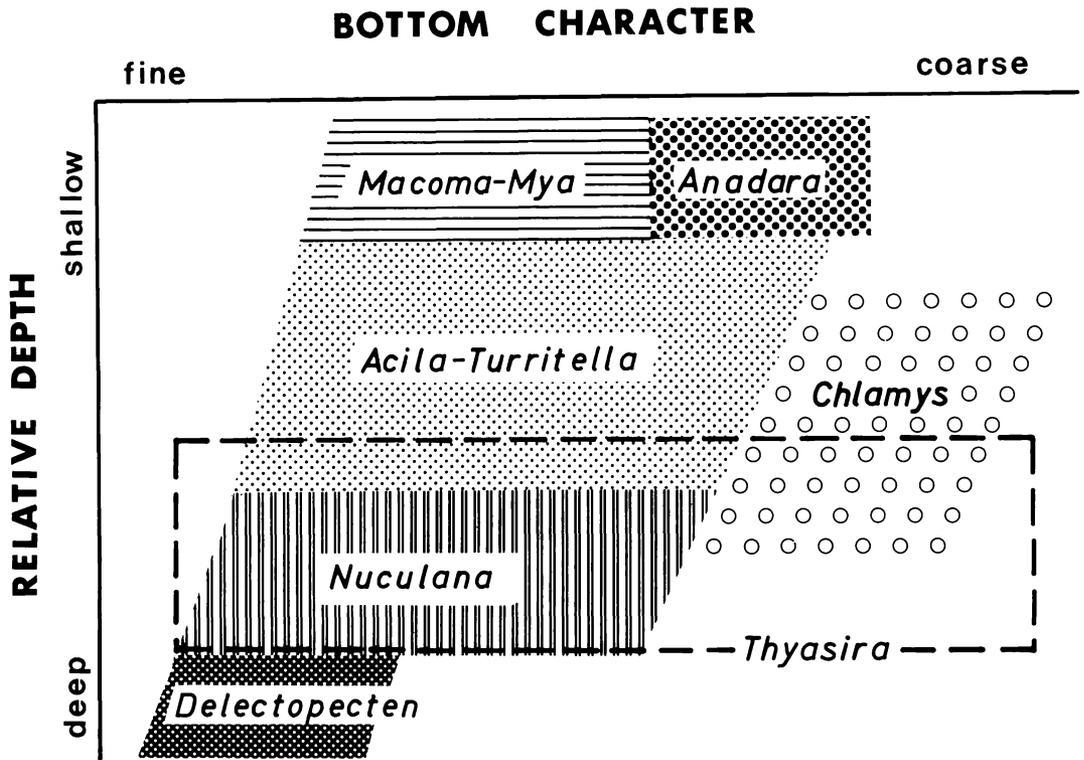


Figure 6. Schematic summary of relation between the association groups and environments expressed in terms of relative water depth and bottom character.

### Summary

Late Cenozoic cold water molluscan associations in Japan are grouped into the seven association groups. The associations belonging to one of these groups are similar to each other not only in species or genus composition but also in environmental preference, though their occurrences are scattered over the interval of approximately 5 million years. The associations are in ecologically parallel relationships with each other. The distribution of the association groups is concluded to have been controlled mainly by water depth and bottom character (Figure 6). There are comparable living benthic molluscan associations around Japan ranging from the bathyal to upper sublittoral zones. The following is characteristics of the association groups.

(1) The *Delectopecten* Association Group

is monospecific, composed of *Delectopecten peckhami*. This is found in the deepest muddy environment. Comparable thin-shelled pectinid fauna is known from the bathyal zone.

(2) The *Nuculana* Association Group is dominated by nuculanid bivalves and carnivorous gastropods such as buccinid species. This group occupies a deep muddy environment but shallower than that of the *Delectopecten* Association Group. Similar living nuculanid and buccinid faunas are commonly found in the muddy upper bathyal zone.

(3) The *Acila-Turritella* Association Group is the commonest type of associations among the latest Miocene to early Pleistocene faunas in Northeast Japan. Various suspension- and deposit-feeding bivalves such as *Clinocardium*, *Macoma* and *Mya* besides some species of *Acila* and *Turritella* prevail in the group. This group appears in silty and

fine-grained sandy sediments representing an environment shallower than that of the *Nuculana* Association Group. The faunas on silty and sandy bottoms of the lower sublittoral zone are comparable with this group.

(4) The *Anadara* Association Group appears in the shallowest sandy environment, composed of *Anadara*, *Scapharca* and other large suspension-feeding bivalves. Sandy molluscan faunas of the upper sublittoral zone are the living analogue of this group.

(5) The *Macoma-Mya* Association Group was a dweller on shallow muddy bottoms adjoining the sandy environment of the *Anadara* Association Group.

(6) The *Thyasira* Association Group is composed of *Thyasira bisecta* and *Lucinoma acutilineata*. This group had a broad tolerance to substrate types but might be restricted to a reducing environment. This had a depth preference similar to the *Nuculana* Association Group.

(7) The *Chlamys* Association Group is composed of epifaunal and shallow-burrowing bivalves. This occupied coarse sand bottoms adjoining to the finer bottoms inhabited by the *Acila-Turritella* and *Nuculana* Association Groups.

These association groups show geographic and historic changes of composition in species level, though the genus compositions have remained unchanged. The geographic replacement of species within the same genus is exemplified by *Turritella* in the *Acila-Turritella* Association Group. This difference may be due to biogeographic provincialism. The Anadarinae of the *Anadara* Association Group is occupied by *Anadara amicula* from the Pliocene through earlier Early Pleistocene, whereas replaced with some species of *Scapharca* in the late Early Pleistocene Omma fauna. The historic changes of the cold water faunas during the Pliocene and Pleistocene will be discussed in another article (Matsui, in prep.).

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Kushiro 釧路, Maekawa 前川, Nishiyama 西山, Oga 男鹿, Omma 大桑, Sado 佐渡, Sagami 相模, Sannohe 三戸, Sendai 仙台, Setana 瀬棚, Shichiba 質場, Taihei 太平, Tsubata 津幡, Uonuma 魚沼.

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中北部日本の鮮新一更新世貝類群集及びその環境との関係：日本の中新世末期から更新世に及ぶ約 500 万年間の寒流系貝類動物群中に 7 つの群集のグループが認められた。それぞれのグループを構成する地域群集はお互いに種または属組成のみならず環境との関係も類似し、お互いに生態的平行の関係にある。群集のグループの分布は主に水深と底質に規制される。また、これらの群集のグループに対応する現生の群集が日本周辺海域に認められる。7 つのグループのなかで *Acila-Turritella* 群集が最も普遍的で、現生の下部浅海帯群集に比較される。*Delectopecten* 群集と *Nuculana* 群集はこれより深い環境に認められる。*Anadara* 群集と *Macoma-Mya* 群集は浅海環境を代表し、それぞれ上部浅海帯の砂底と泥底群集に比較される。*Thyasira* 群集は還元的な環境と結びついていたと考えられる。*Chlamys* 群集は下部浅海帯及び上部漸深海帯の粗粒砂底を代表する。松居誠一郎

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## 911. A NEW GENUS OF THE TREMATOPHORATE MILIOLIDS (FABULARIIDAE) FROM THE EOCENE SETOGAWA GROUP, SOUTHWEST JAPAN\*

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**Abstract.** This paper deals with the description and illustration of a new genus of the trematophorate miliolids (Fabulariidae), *Neolacazopsis osozawai*, n. gen., n. sp., from the basaltic and calcareous sandstone of the Eocene Setogawa Group, at Ashikubo-Okugumi, Shizuoka City and at Hasama, Okabe-Cho, both of Shizuoka Prefecture, Japan.

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**Key words.** *Neolacazopsis osozawai*, Eocene, Setogawa Group, Shizuoka Prefecture.

### Introduction

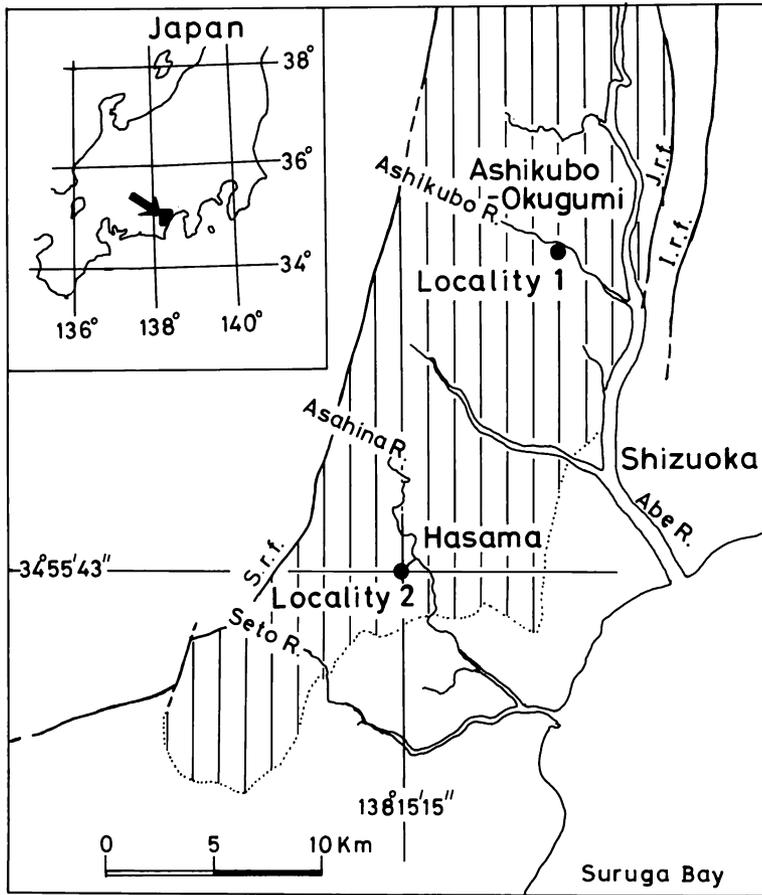
In 1989, Soichi Osozawa, Institute of Geology and Paleontology, Tohoku University, discovered two new localities of larger foraminifer bearing-limestone at Ashikubo-Okugumi, northwest of Shizuoka City and Hasama, northwest of Okabe-cho, both of Shizuoka Prefecture, and kindly sent the fossil materials to the author for study (Figure 1). Afterwards, the author visited Osozawa's fossil localities with author's working group in order to gather a number of fossil materials and to get the stratigraphical information. At Ashikubo-Okugumi locality, the fossil-bearing limestone samples were taken as a rolling stone of boulder sized limestone conglomerates from the Setogawa Group. Samples at Hasama locality were taken directly from the basaltic and calcareous sandstone exposure of the Setogawa Group. Both samples from the two localities treated in this paper were studied in detail and they were the same limestone, which contains the trematophorate miliolids (Fabulariidae), other

benthic and planktic foraminifers, calcareous algae, bryozoan, molluscs, echinoids and others.

According to the recent stratigraphical and tectonical studies of Osozawa (1988), the area of the two fossil localities is constituted of the Eocene to lower Miocene Setogawa Group, which consists of pelagic, hemipelagic, and terrigenous sediments with volcanic intercalations. The basaltic and calcareous sandstone of the stratigraphic sequence of the Setogawa Group includes fragments of basalt and limestone. On the whole, Osozawa (*op. cit.*) considered the Setogawa Group to be an accretionary complex on the basis of the occurrences of pelagic sediments on land, repeated stratigraphic sequence caused by reverse faulting and asymmetric folding. Sugiyama and Shimokawa (1981) considered the fossil-bearing limestone to be a special lithology of biosparite in the uppermost part of the Takisawa Formation, Setogawa Group. Formerly, Ishii and Makino (1946) found *Discocyclina* from the limestone of the Setogawa Series and regarded to be of the Danian to Upper Eocene. Recently, Ibaraki (1984) regarded the limestones of the Setog-

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**Figure 1.** Map showing the fossil locality of the studied area, Shizuoka Prefecture. Vertical lines represent the distribution of the Setogawa Group. S.r.f.: Sasayama reverse fault, J.r.f.: Jyumaiyama reverse fault, I.r.f.: Itoigawa-Shizuoka reverse fault.

awa Group to be assigned to the Middle to Late Eocene (Blow's Zone of P12 to P16) based on planktic foraminifers. As can be seen in Figure 4-1, it is obvious that the age of the fossil-bearing limestone is younger than the Middle Eocene based on the presence of *Triloculina*, ranging from the Middle Eocene to Holocene (Loeblich and Tappan, 1988).

The purpose of this paper is to make the first description and discussion of the new type forms of the trematophorate miliolids in

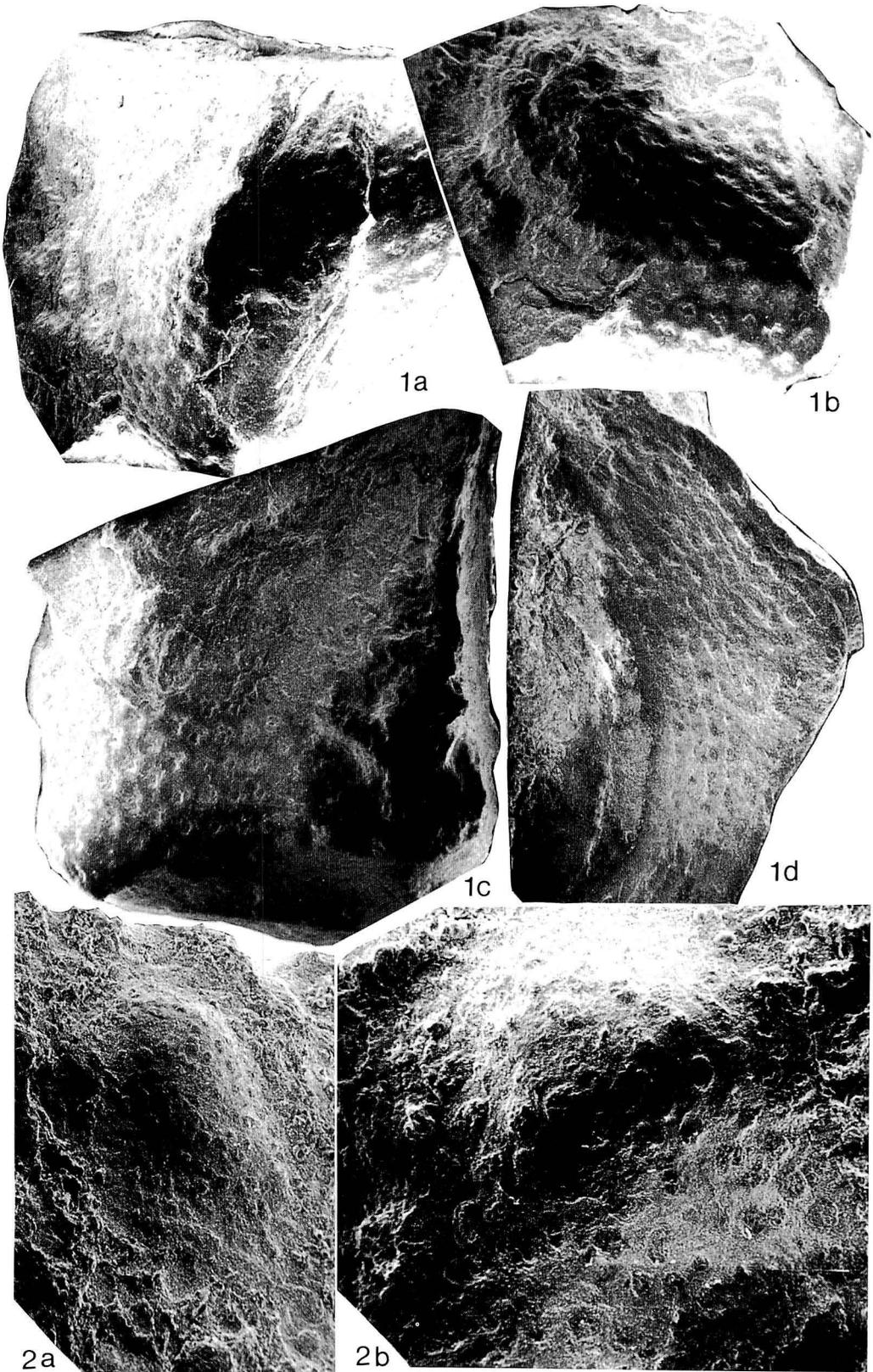
Japan, and to propose a new genus name *Neolacazopsis* for new type ones, taking *Neolacazopsis osozawai*, n. gen., n. sp., as the type species.

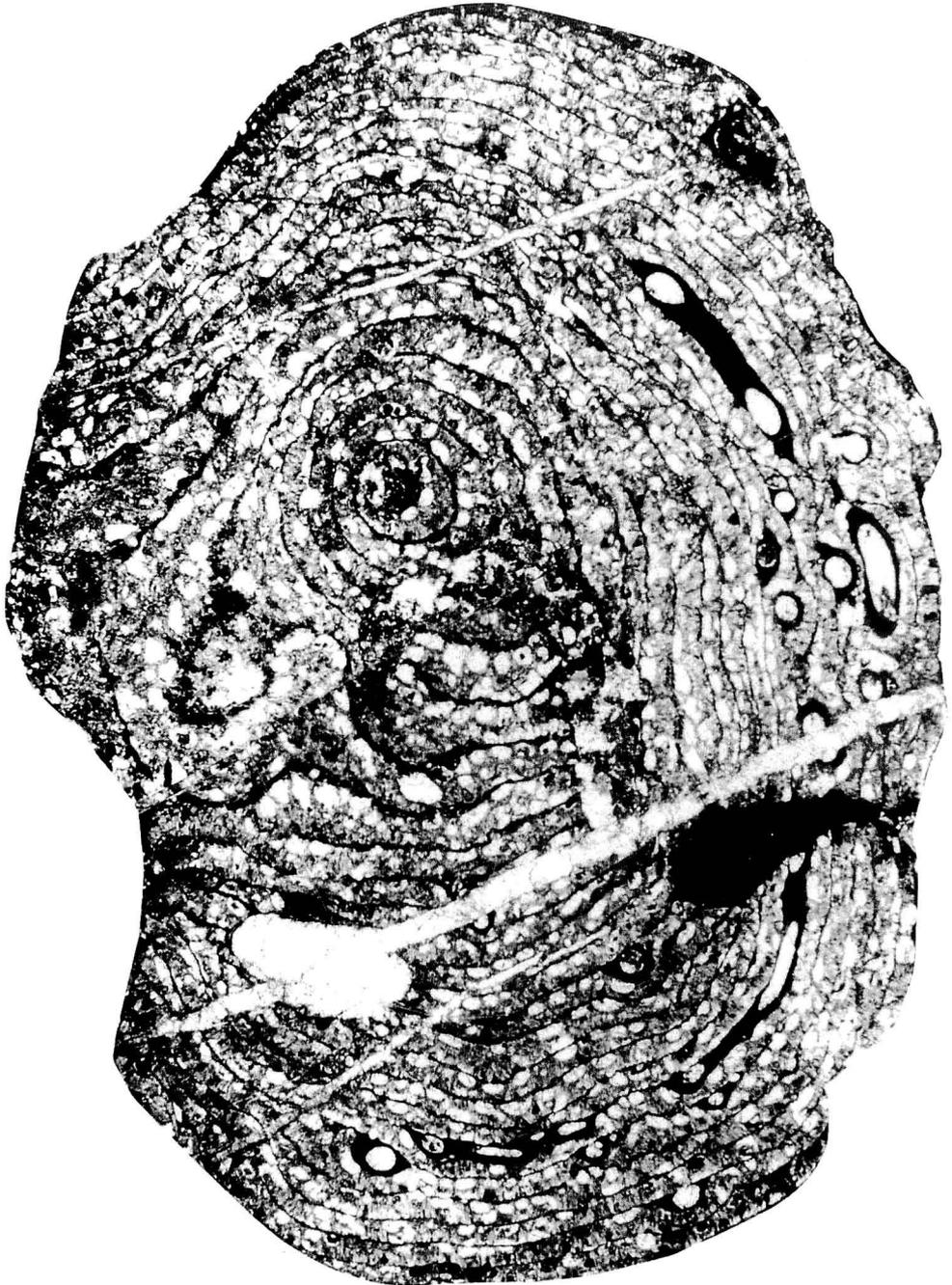
### Systematic description

Superfamily Alveolinacea Ehrenberg, 1839  
 Family Fabulariidae Ehrenberg, 1839  
 Genus *Neolacazopsis* Matsumaru, n. gen.

Type species.—*Neolacazopsis osozawai*

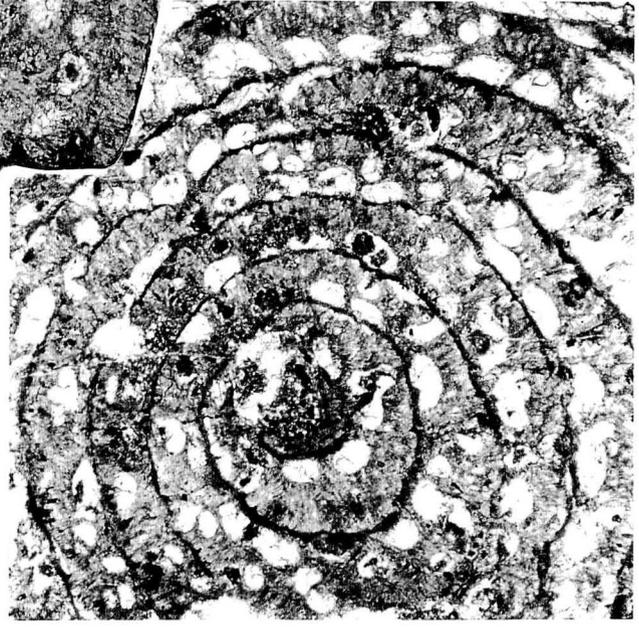
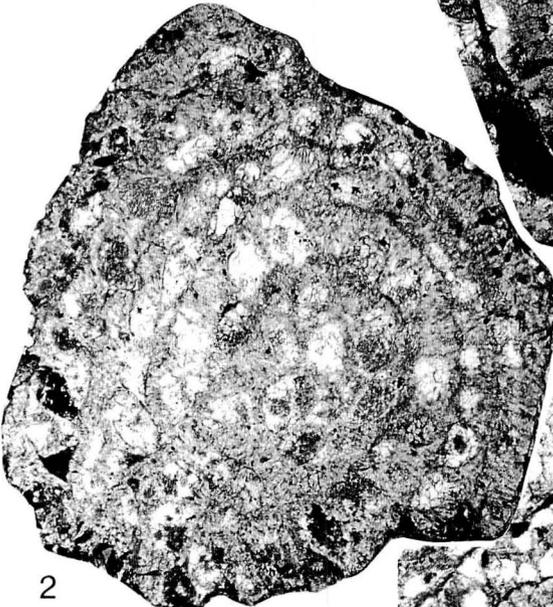
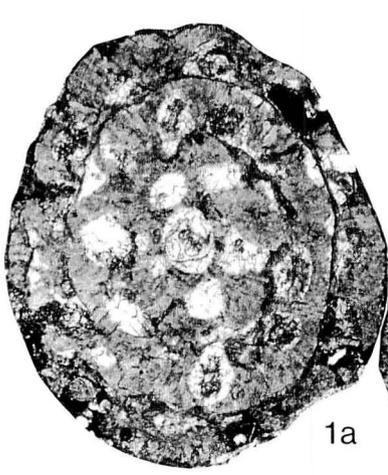
→ **Figure 2.** *Neolacazopsis osozawai* Matsumaru, n. gen., n. sp. All figures  $\times 15$ , except  $\times 50$  of **2b**; Locality 2. **1a-b**, **2a**, lateral views of parts of specimens; **1c**, **2b**, horizontal views, showing the external shape and arrangement of chamberlets; **1d**, Inside of **1a**, showing the arrangement of epidermal chambers and their chamberlets.





**Figure 3.** *Neolacazopsis osozawai* Matsumaru, n. gen., n. sp. Equatorial section of a microspheric specimen, holotype, Saitama University, Coll. no. 8804,  $\times 10$ ; Locality 1.

→ **Figure 4.** *Neolacazopsis osozawai* Matsumaru, n. gen., n. sp. All figures  $\times 20$ , except  $\times 40$  of **1b**; Locality 1. **1, 3**, Equatorial sections of both megalospheric specimen (**1**) and microspheric one (**3**); **1b**, Enlarged twice **1a**, showing the large proloculus, which includes *Triloculina* cf. *subvalvularis* Parr, followed by chambers in biloculine arrangement. Paratype, Saitama University, Coll. no. 8805; **2**, Oblique section of a megalospheric specimen.



Matsumaru, n. sp.

*Diagnosis.*—Test large, elongate ovate in outline; large proloculus followed by chambers in biloculine arrangement in megalospheric form, microspheric test with quinqueloculine at first stage, then triloculine to biloculine, adult of both generations has completely enveloping biloculine chambers added alternately from pole to pole, then followed by enveloping epidermal chambers; biloculine and epidermal chambers subdivided into arcuate to turtle-neck bottle-like form chamberlets by longitudinal and transverse interseptal partitions and pillars among congregations of previous both partitions; wall calcareous, porcellaneous, with thick and finely to coarsely alveolar inner layer, outer layer thin and finely to coarsely perforate, bilamellar; aperture terminal, with a trematophore-like elongate arcuate shape bearing numerous irregular openings separated by anastomosing denticulations or cribrate.

*Comparison.*—The present genus resembles *Lacazopsis* H. Douvillé 1930, but is distinguished from the latter by having calcareous and porcellaneous wall of test, and trematophore-like aperture. *Lacazopsis* was classified as one of the genus in the Subfamily Fabulariinae Ehrenberg, 1839, of Family Miliolidae Ehrenberg, 1839 by Loeblich and Tappan (1964), but they (1988) rejected *Lacazopsis* as one of the genus taxa erroneously regarded as foraminifers, because of a taxon of an encrusting cheilostome bryozoan. *Neolacazopsis* also resembles *Lacazina* Munier-Chalmas, 1882, but is distinguished from the latter by having an elongate arcuate shape aperture and trematophore, and by having alveolar wall in early stage in microspheric form.

*Neolacazopsis osozawai* Matsumaru, n. sp.

Figures 2–7

*Type material.*—Holotype, equatorial section of microspheric specimen, Saitama Uni-

versity Coll. no. 8804 (Figures 3, 4–3). Paratype, equatorial section of megalospheric specimen, Saitama University Coll. no. 8805 (Figures 4–1a–b).

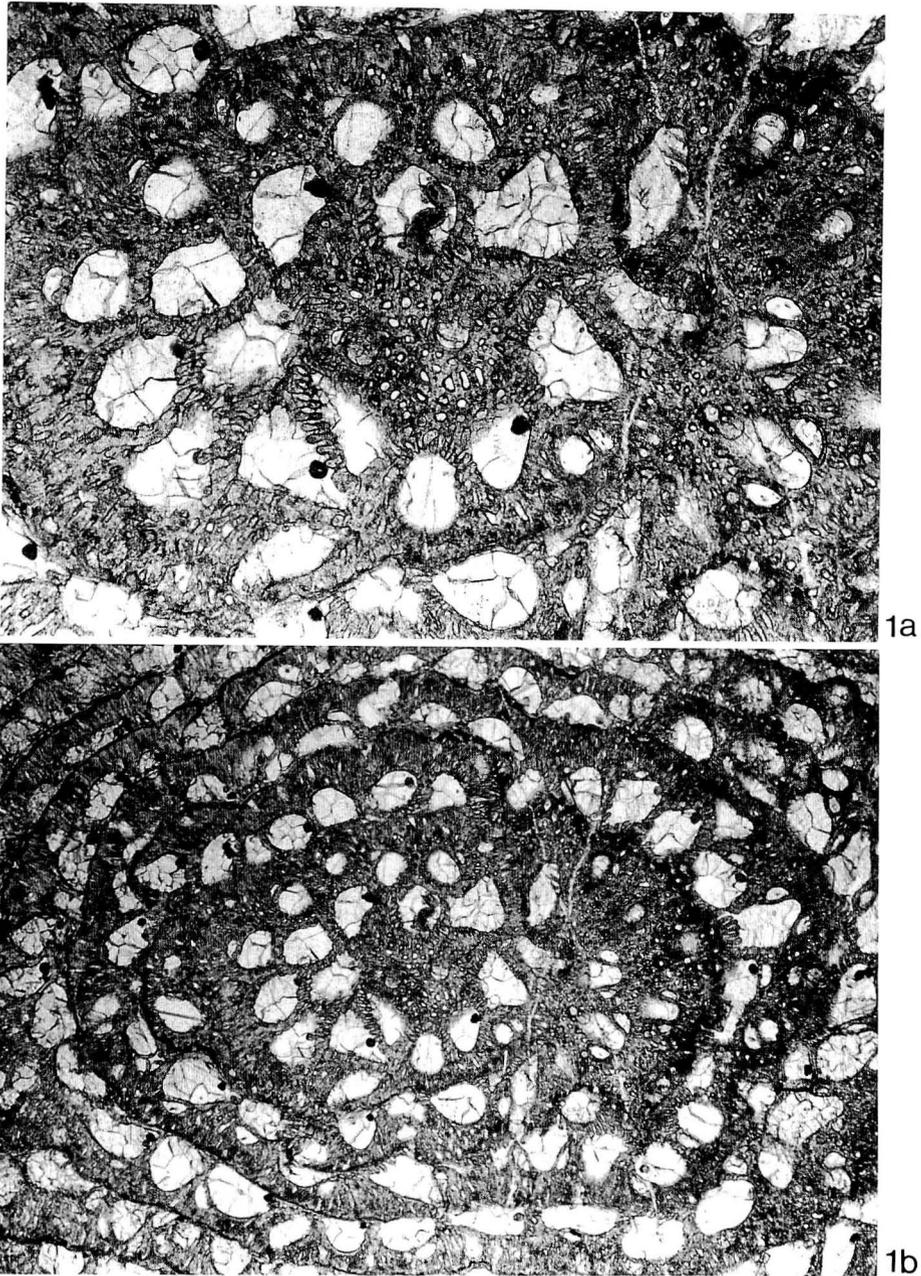
*Description.*—The microspheric specimens (Figures 3, 4–3, 5, 6, 7) are large elongate ovate test with diameter of 17 to 35 mm, and thickness of 13 to 20 mm. The megalospheric specimens (Figures 4–1–2) are small ovate test with more than 4 mm in diameter and more than 2.2 mm in thickness in some broken specimens. Surface bears widely reticulation, which represents the surface expression of the chamberlet sutures of test walls. The diameter of chamberlet on surface is 100 to 200  $\mu\text{m}$ . The first stage of quinqueloculine chambers in microspheric form has outer diameters of 560 to 580  $\mu\text{m}$ . The second stage of triloculine chambers, which embrace the quinqueloculine, has outer diameters of 750 to 1150  $\mu\text{m}$ . The large megalospheric proloculus is subspherical, with inner diameters of 376  $\times$  306  $\mu\text{m}$ . The early chambers of both microspheric and megalospheric forms are followed by arcuate to elongate arcuate biloculine chambers added alternately from pole to pole of test, and by elongate arcuate epidermal chambers. The main biloculine chambers in microspheric form in transverse section are with radial diameters of 370 to 380  $\mu\text{m}$  and tangential diameters of 1.2 to 2 mm near the triloculine chambers to radial diameters of 270 to 300  $\mu\text{m}$  and tangential diameter of 8 to 10 mm near the peripheral part of test. Biloculine and epidermal chambers are subdivided into arcuate to turtle-neck bottle-like form chamberlets by longitudinal and transverse interseptal partitions and pillars. Typical chamberlets with dimension of 170  $\times$  357, 204  $\times$  408, 238  $\times$  408, 306  $\times$  300, 510  $\times$  272 and 544  $\times$  272  $\mu\text{m}$  in inner radial and tangential diameters. The wall calcareous and porcellaneous, thick and finely to coarsely alveolar inner layer, outer layer thin and finely to coarsely perforate bilamellar, measuring thickness of 100 to 238  $\mu\text{m}$  near the center to 60 to 100  $\mu\text{m}$  near the periphery. The aper-



**Figure 5.** *Neolacazopsis osozawai* Matsumaru, n. gen., n. sp. Tangential section of a microspheric specimen, showing the trematophorate aperture (arrow) and completely enveloping biloculine and epidermal chambers,  $\times 15$ ; Locality 2.



**Figure 6.** *Neolacazopsis osozawai* Matsumaru, n. gen., n. sp. Transverse section of a microspheric specimen, showing arcuate to turtle-neck bottle-like form chamberlets,  $\times 15$ ; Locality 1.



**Figure 7.** *Neolacazopsis osozawai* Matsumaru, n. gen., n. sp. **1a**, Enlarged of Figure 6  $\times 48$ , showing chambers near centre in triloculine arrangement in a microspheric generation, and showing the wall with coarsely alveolar inner layer; **1b**, Enlarged Figure 6  $\times 24$ , showing chambers from triloculine to biloculine arrangement, added from pole to pole.

ture at the base of the preceding chamber in tangential section consisting of trematophore with irregular openings (Figure 5).

*Locality.*—Locality 1 is a tributary river of the Ashikubo River, at the opposite side of Ashikubo-Okugumi, Shizuoka City (35°3'38" N. Lat., 138°19'43" E. Long.) and locality 2 is a tributary river (Kamiiri-sawa) of the Asahina River at the opposite side of Hasama, Okabe-cho, Shida-Gun (34°55'43" N. Lat., 138°15'15" E. Long.), both of Shizuoka Prefecture (Figure 1).

*Stratigraphical horizon.*—Basaltic and calcareous sandstone, Setogawa Group or Taki-sawa Formation, Setogawa Group.

*Geological age.*—Middle to Late Eocene.

*Remarks.*—*Neolacazopsis osozawai*, n. sp. resembles *Lacazopsis termieri* H. Douvillé, 1930 from the Upper Cretaceous (Senonian) in Morocco, northwest Africa, but is distinguished from the latter by having calcareous and porcellaneous wall of test, turtle-neck bottle-like chamberlets, alveolar inner wall and trematophore-like aperture. The present new species differs from *Lacazina compressa* (d'Orbigny) var. *galloprovincialis* Munier-Chalmas and Schlumberger, 1885 from the Senonian, Martigues, France in having turtle-neck bottle-like chamberlets and alveolar inner wall instead of arcuate chamberlets and imperforate inner wall.

#### Acknowledgment

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Ashikubo-Okugumi 足久保奥組, Hasama 羽佐間, Okabe-Cho 岡部町, Setogawa 瀬戸川, Takisawa 滝沢, Kamiiri-Sawa 神入沢, Asahina 朝比奈, Shida-Gun 志太郡.

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瀬戸川層群からの Trematophorate miliolids (Fubulariidae 科) の 1 新属: 静岡県静岡市北西の足久保奥組および同県志太郡岡部町羽佐間の神入沢の瀬戸川層群玄武岩質石灰質砂岩から, 始新世中一後期の trematophorate miliolids (Fubulariidae 科) の 1 新属を発見し, 記載した。それは遅沢壮一氏から本研究の機会を得た関係から, *Neolacazopsis osozawai* Matsumaru, n. gen., n. sp. と命名した。この新属新種は *Lacazopsis* 属 (H. Douvillé, 1930) および *Lacazina* 属 (Munier-Chalmas, 1882) に近似し, 詳細に比較検討した。松丸国照

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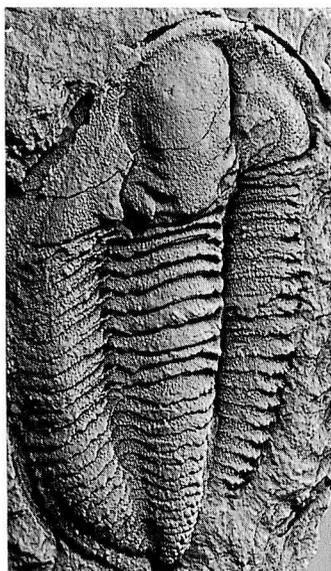
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# 日本古生物学会 報告・紀事

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日本古生物学会  
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The heading in Japanese commemorates the handwriting of Prof. Matajiro YOKOYAMA, father of Japanese palaeontology, who was a professor of stratigraphy and palaeontology at the Geological Institute, Imperial University of Tokyo.

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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## 行事予定

- ◎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。  
◎1991年例会(第140回例会)は6月22, 23日に千葉県立中央博物館(☎0472(65)3111)で開催されます。講演申込は1991年4月30日(必着)ですが、1991年年会から講演申込の方法が変更になっていますので注意して下さい。詳しくは「化石」48号をご覧下さい。

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