

Planktonic Gastropods from the Miocene First Setouchi Series in the Setouchi Geologic Province, Southwest Japan

Hiroshi SHIBATA*

瀬戸内地質区の中新統第一瀬戸内累層群産の浮遊性腹足類

柴田 博*

(要 旨)

瀬戸内地質区の9地域の中新統, 岩村, 瑞浪, 師崎, 一志, 鮎河, 山粕, 山辺および備北層群と千種累層から浮遊性腹足類の化石が発見されている。それらは, 10種の翼足類, *Limacina* sp., *Euclio balan-tium* (RANG), *Euclio* sp. A, *Euclio* sp. B, *Vaginella depressa* DAUDIN, *Bowdenatheca* sp., *Cavolinia raritatis* (NOMURA and ZINBO), *Cavolinia* sp. A, *Cavolinia* sp. B, *Cavolinia* ? sp. C と1種の異足類, *Atlanta* sp. よりなる。これらは, 暖海域に生息した表層浮遊性の種であると考えられる。それぞれの種は, 第一瀬戸内累層群においては限られた層準のみより産出しており, したがって, 同累層群の対比に役立つと考えられる。

Introduction

Planktonic gastropods are now known from the Miocene First Setouchi Series of nine areas in the Setouchi geologic province, southwest Honshu. Previously reported occurrences of such gastropods are from the Ichishi Group in the Ichishi basin (SHIBATA, 1967, 1970), the Chikusa Formation in Komono-cho, Mie-gun (HATA, 1967), the Yamabe Group in the eastern Yamato Highlands (SHIIDA and SHIBATA, 1968), the Mizunami Group in the Mizunami basin (ITOIGAWA, SHIBATA and NISHIMOTO, 1974) and the Bihoku Group in Osa-cho, Okayama Prefecture (ITOIGAWA and NISHIKAWA, 1976). Extensive recent collecting has revealed their presence in the First Setouchi Series of five other areas. They are the Morozaki Group on Chita Peninsula, the Iwamura Group in the Iwamura basin, Gifu Prefecture, the Yamagasu Group in Misugi-mura, Mie Prefecture and the Ayugawa Group in Tsuchiyama-cho, Shiga Prefecture. Further it has produced additional collections from the Ichishi and Mizunami Groups. The collections from the Mizunami Group have been supplemented by collections from the Mizunami Fossil Museum. The author has examined collections from all known Setouchi occurrences.

* Laboratory of Geology, College of General Education, Nagoya University, Nagoya
名古屋大学教養部地学教室

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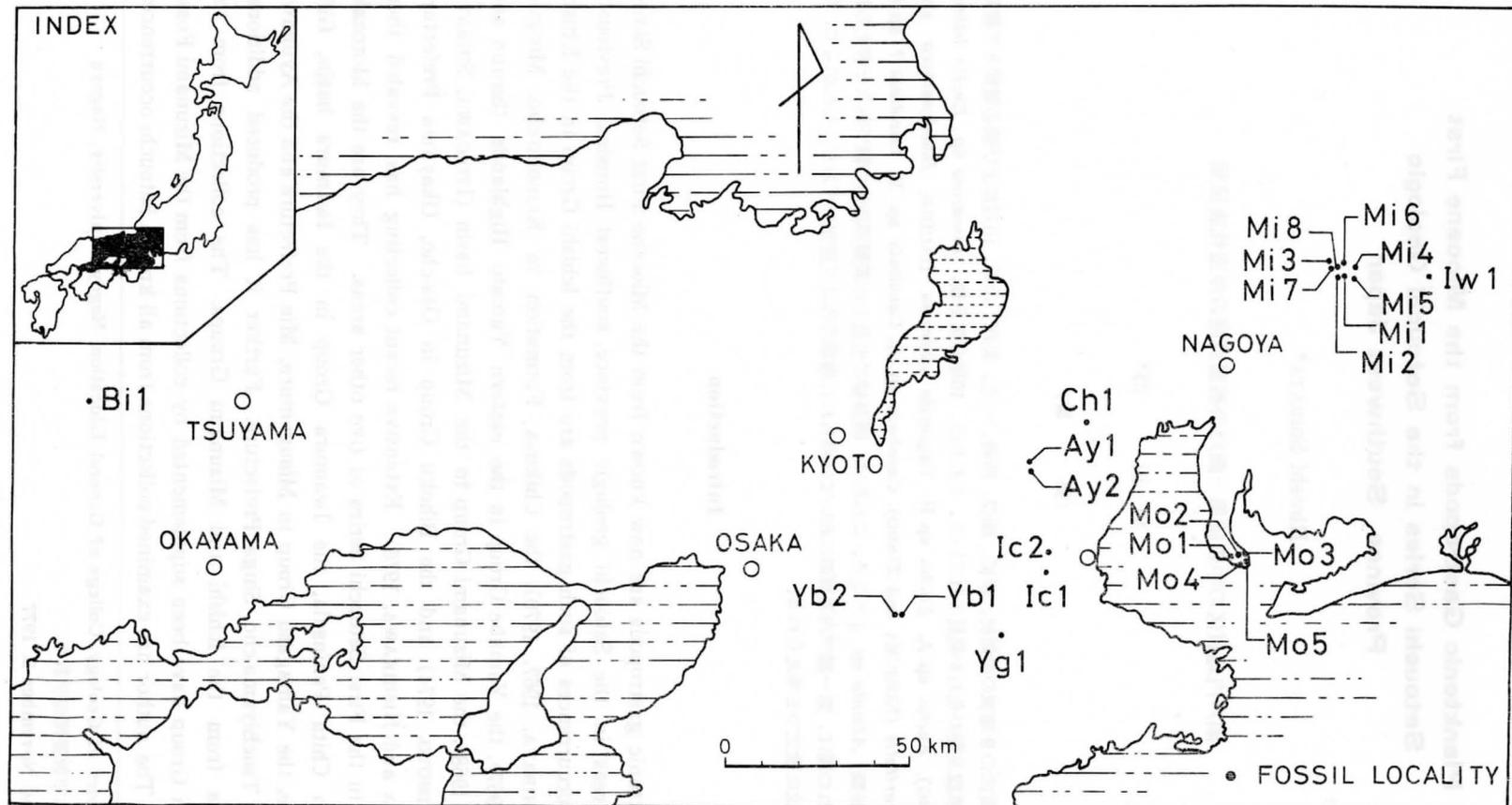


Fig. 1. General location of fossil localities in the Setouchi Geologic Province. For precise locations, see text.

Table 1. List of planktonic gastropoda from the First Setouchi Series.

Species	Localities																						
	Iw	Mi	Mo	Mo	Mo	Mo	Mo	Ch	Ic	Ic	Ay	Ay	Yg	Yb	Yb	Bi							
<i>Atlanta</i> sp.	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Limacina</i> sp.	-	A	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Euclio balantium</i> (RANG)	R	F	-	-	-	-	-	-	-	R	R	-	-	F	-	R	F	-	-	R	-	-	-
<i>Euclio</i> sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	R	-	-	-	-
<i>Euclio</i> sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-
<i>Vaginella depressa</i> DAUDIN	-	R	-	R	-	R	R	-	-	-	F	R	R	F	A	A	F	R	R	-	-	-	-
<i>Bowdenathea</i> sp.	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	F	R	-	-	-	-	-	-
<i>Cavolinia raritatis</i> (NOMURA and ZINBO)	-	A	R	R	F	-	-	C	R	-	-	-	-	-	R	C	R	-	-	-	-	-	-
<i>Cavolinia</i> sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	C
<i>Cavolinia</i> sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
<i>Cavolinia</i> ? sp. C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-

A: more than 25 specimens C: 10-25 specimens F: 5-10 specimens

R: less than 5 specimens

Ten pteropodous species and one heteropodous species are represented in the collections. This paper assesses their value for correlation within the Setouchi geologic province, and interprets their paleoecology principally on the basis of associated benthonic mollusks. Miocene planktonic gastropods have been reported only a few areas (NOMURA and ZINBO, 1935, NODA, 1972) in Japan except the areas mentioned above.

Acknowledgements

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Localities and Stratigraphy

Planktonic gastropods are known from twenty-three localities (Fig. 1). Table

1 indicates taxa and their abundance at individual fossil sites. The location, lithology, stratigraphic horizon and principal forms among associated benthonic mollusks are given below for each locality.

Iwamura Group

Description of the stratigraphy of the Group can be found in ITOIGAWA(1955).

Locality Iw 1. Stream bed of a branch of the Agi River, approximately 1 kilometer southeast of Dota, Nakatsugawa City, Gifu Prefecture.

Lithology and stratigraphic horizon; mudstone of the Ryodenji Formation.

Principal benthonic mollusks; *Acilana tokunagai* (YOKOYAMA), *Yoldia sagittaria* YOKOYAMA.

Mizunami Group

In addition to previously reported five localities (ITOIGAWA, SHIBATA and NISHIMOTO, 1974), three localities were discovered. Locality Mi 1, locality Mi 2, locality Mi 4, locality Mi 5 and locality Mi 6 are equivalent to ITOIGAWA, SHIBATA and NISHIMOTO's locality 77, locality 87, locality 38, locality 35 and locality 18, respectively. Description of the stratigraphy of the Group can be found in ITOIGAWA (1960, 1974).

Locality Mi 1. Road cut of Chuo Highway 350 meters southeast of the Mizunami Fossil Museum, Akeyo-cho, Mizunami City, Gifu Prefecture.

Lithology and stratigraphic horizon; mudstone of the Oidawara Mudstone.

Principal benthonic mollusks; *Acharax tokunagai* (YOKOYAMA), *Bathymalletia chitensis* SHIKAMA and KASE, *Neilonella* cfr. *soyoe* HABE, *Portlandia watasei* (KANEHARA) var., *Periploma mitsuganoense* ARAKI, *Poromya flexuosa* YOKOYAMA, *Cuspidaria* sp., *Ancistrolepis togariensis miensis* ARAKI, *Nipponoscaphander* sp.

Locality Mi 2. Road cut of Chuo Highway 150 meters southwest of the Mizunami Fossil Museum, Akeyo-cho, Mizunami City.

Lithology and stratigraphic horizon; sandy mudstone of the Oidawara Mudstone.

Principal benthonic mollusks; *Neilonella* cfr. *soyoe* HABE, *Lucinoma acutilineatum* (CONRAD), *Macoma* sp., *Periploma mitsuganoense* ARAKI.

Locality Mi 3. Road cut of the gateway to Akeyo Country Club about 500 meters west of Garaishi, Akeyo-cho, Mizunami City.

Lithology and stratigraphic horizon; mudstone of the Oidawara Mudstone.

Principal benthonic mollusks; *Ennucula osawanoensis* (TSUDA), *Neilonella* cfr. *soyoe* HABE, *Palliolium (Delectopecten) peckhami* (GABB), *Fissidentalium* sp., *Microglyphis mitsuganoensis* SHIBATA.

Locality Mi 4. Road cut 250 meters northwest of Nataki, Toki-cho, Mizunami City.

Lithology and stratigraphic horizon; mudstone of the Oidawara Mudstone.

Principal benthonic mollusks; *Acharax tokunagai* (YOKOYAMA), *Bathymalletia*

chitensis SHIKAMA and KASE, *Acilana tokunagai* (YOKOYAMA), *Lucinoma acutilineatum* (CONRAD), *Laevidentalium* sp., *Microglyphis mitsuganoensis* SHIBATA.

Locality Mi 5. Small cliff along a rill about 500 meters south of Sakurado, Toki-cho, Mizunami City.

Lithology and stratigraphic horizon; conglomerate of the Nataki Conglomerate. Specimens of *Vaginella depressa* DAUDIN were obtained from pebbles of the Nataki Conglomerate just above the unconformable contact between the Nataki and the underlying Toki lignite bearing Formation. ITOIGAWA (1974) states that the pebbles were derived from deposits corresponding to the Shukunohora Sandstone.

Principal benthonic mollusks; *Glycymeris cisshuensis* MAKIYAMA, *Chlamys minoensis* ITOIGAWA, *Turritella* sp., *Noditerebra osawanoensis* (TSUDA).

Locality Mi 6. Floor of the Shukubora River, Shukubora, Hiyoshi-cho, Mizunami City.

Lithology and stratigraphic horizon; sandstone of the Shukunohora Sandstone.

Principal benthonic mollusks; *Glycymeris cisshuensis* MAKIYAMA, *Pillucina* (*Wallucina*) *okumurai* ITOIGAWA, *Cavilucina* (*Monitilora*) *kitamurai* (HATAI and NISIYAMA), *Dosinorbis suketoensis* (OTUKA), *Turbo* (*Marmorostoma*) *ozawai* OTUKA, *Proclava ancisa* (YOKOYAMA), *Polinices mizunamiensis* ITOIGAWA, *Mitrella* sp., *Zeuxis minoensis* ITOIGAWA, *Ringicula minoensis* TAKEYAMA, *Eocylichna habeii* ITOIGAWA, *Eocylichna tokiensis* ITOIGAWA.

Locality Mi 7. Bank of the Hiyoshi River, 1 kilometer southwest of Hongo, Hiyoshi-cho, Mizunami City.

Lithology and stratigraphic horizon; sandstone of the Shukunohora Sandstone.

Principal benthonic mollusks; *Diplodonta ferruginata* MAKIYAMA, "*Littorinopsis*" *miodelicatula* OYAMA, *Schwartziella* sp., "*Vermetus*" sp., *Tateiwaia yamanarii* (MAKIYAMA), *Bittium* sp., *Balcis* sp., *Iselica* sp., *Proterato* (*Sulcerato*) *minoensis* ITOIGAWA, *Mitrella* sp., "*Triphora*" sp.

Locality Mi 8. Stream bed of a branch of the Hiyoshi River about 300 meters southeast of Shuku, Hiyoshi-cho, Mizunami City.

Lithology and stratigraphic horizon; sandstone of the Shukunohora Sandstone.

Principal benthonic mollusks; *Chlamys* sp., *Cavilucina* (*Monitilora*) *kitamurai* (HATAI and NISIYAMA), *Turbo* (*Marmorostoma*) *ozawai* OTUKA.

Morozaki Group

Description of the stratigraphy of the Group and a detailed list of mollusks from it are present in SHIBATA (in press). Locality Mo 1, locality Mo 2, locality Mo 3, locality Mo 4 and locality Mo 5 are equivalent to his locality 33, locality 25, locality 21, locality 17 and locality 16, respectively.

Locality Mo 1. Stone pit beside the road leading from Okkata to Toyohama 1.3 kilometers south of Okkata, Minamichita-cho, Chita-gun, Aichi Prefecture.

Lithology and stratigraphic horizon; shale of the Yamami Formation.

Principal benthonic mollusks; *Acilana tokunagai* (YOKOYAMA), *Periploma*

mitsuganoense ARAKI.

Locality Mo 2. Road cut on the east side of the road leading from Hongo to Toyohama about 1 kilometer north of Toyohama, Minamichita-cho, Chita-gun.

Lithology and stratigraphic horizon; shale of the Toyohama Formation.

Principal benthonic mollusks; *Acila (Truncacila)* sp., *Ennucula* cfr. *osawanoensis* (TSUDA), *Carinineilo takeharai* (SHIBATA), *Neilonella isensis* SHIBATA, *Acilana tokunagai* (YOKOYAMA), *Propeamussium tateiwai* KANEHARA.

Locality Mo 3. Cliff 300 meters northwest of Katana, Minamichita-cho, Chita-gun.

Lithology and stratigraphic horizon; shale of the Toyohama Formation.

Principal benthonic mollusks; *Acila (Truncacila)* sp., *Ennucula* cfr. *osawanoensis* (TSUDA), "*Neilonella*" *ovata* (TAKEDA), *Acilana tokunagai* (YOKOYAMA), *Propeamussium tateiwai* KANEHARA, *Palliolum (Delectopecten) peckhami* (GABB), *Periploma mitsuganoense* ARAKI, *Tectonatica ichishiana* SHIBATA.

Locality Mo 4. Road-side cliff about 1 kilometer east of Morozaki, Minamichita-cho, Chita-gun.

Lithology and stratigraphic horizon; shale of the Toyohama Formation.

Principal benthonic mollusks; *Acila (Truncacila)* sp., *Carinineilo takeharai* (SHIBATA), "*Neilonella*" *ovata* (TAKEDA), *Acilana tokunagai* (YOKOYAMA), *Propeamussium tateiwai* KANEHARA, *Palliolum (Delectopecten) peckhami* (GABB), *Calyptogena* sp., *Lucinoma acutilineatum* (CONRAD), *Tectonatica ichishiana* SHIBATA.

Locality Mo 5. Stone pit 500 meters south of Katana, Minamichita-cho, Chita-gun.

Lithology and stratigraphic horizon; mudstone of the Toyohama Formation.

Principal benthonic mollusks; *Acharax tokunagai* (YOKOYAMA), *Acila (Truncacila)* sp., *Carinineilo takeharai* (SHIBATA), "*Neilonella*" *ovata* (TAKEDA), *Acilana tokunagai* (YOKOYAMA), *Propeamussium tateiwai* KANEHARA, *Palliolum (Delectopecten) peckhami* (GABB), *Calyptogena* sp., *Lucinoma acutilineatum* (CONRAD), *Tectonatica ichishiana* SHIBATA.

Chikusa Formation

HATA (1967) reported *Cuvielina* sp. which is referred to *Vaginella depressa* DAUDIN from his locality 1. Attempts to gain additional specimens were unsuccessful. According to him the location of the fossil locality which is represented by locality Ch 1 in this paper, the enclosing sediment and associated benthonic mollusks are as follows.

Locality Ch 1. Bank of a rill about 2.4 kilometers west of Sugitani, Komonocho, Mie-gun, Mie Prefecture.

Lithology; sandstone.

Benthonic mollusks; *Ostrea* sp., *Cyclocardia siogamensis* (NOMURA), *Macoma* sp.

Ichishi Group

SHIBATA (1970) reported three pteropodous species from two localities. Three additional species were discovered in new collections from these localities. Locality Ic 1 and locality Ic 2 are equivalent to his locality k73 and locality k35, respectively.

Locality Ic 1. Road cut at Yamato, Hakusan-cho, Ichishi-gun, Mie Prefecture.

Lithology and stratigraphic horizon; mudstone of the Mitsugano Member.

Principal benthonic mollusks; *Carinineilo takeharai* (SHIBATA), *Neilonella isensis* SHIBATA, *Portlandia watasei* (KANEHARA), *Solamen fornicatum* (YOKOYAMA), *Acesta goliath* (SOWERBY), *Cyclocardia siogamensis* (NOMURA), *Macoma izurensis* (YOKOYAMA), *Periploma mitsuganoense* ARAKI, *Ancistrolepis togariensis* NARUSE, *Microglyphis mitsuganoensis* SHIBATA.

Locality Ic 2. Floor of the Nagano River at Ashisaka, Misato-mura, Age-gun.

Lithology and stratigraphic horizon; mudstone of the Mitsugano Member.

Principal benthonic mollusks; *Carinineilo takeharai* (SHIBATA), *Neilonella isensis* SHIBATA, *Portlandia watasei* (KANEHARA), *Propeamussium tateiwai* KANEHARA, *Palliolum (Delectopeten) peckhami* (GABB), *Periploma mitsuganoense* ARAKI, *Tectonatica ichishiana* SHIBATA.

Ayugawa Group

Stratigraphic data on the Group are given by IKEBE (1934).

Locality Ay 1. Stream bed of a brook 270 meters southeast of Nakahata Bridge, Tsuchiyama-cho, Koga-gun, Shiga Prefecture.

Lithology and stratigraphic horizon; sandstone of the Akebihara Sandstone.

Principal benthonic mollusks; *Saccella miensis* (ARAKI), *Moerella* sp., *Siliqua minoensis* ITOIGAWA, *Turritella sagai* KOTAKA.

Locality Ay 2. Exposure 200 meters northwest of Ohira Bridge, Tsuchiyama-cho, Koga-gun.

Lithology and stratigraphic horizon; sandstone of the Akebihara Sandstone.

Principal benthonic mollusks; *Acila submirabilis* MAKIYAMA, *Saccella miensis* (ARAKI), *Clinocardium andoi* ITOIGAWA and SHIBATA, *Phaxas izumoensis* (YOKOYAMA), *Phos minoensis* ITOIGAWA.

Yamagasu Group

Description of the stratigraphy of the Group can be found in SHIDA and others (1960).

Locality Yg 1. Cliff on the north slope of Mt. Ohora, Misugi-mura, Ichishi-gun, Mie Prefecture.

Lithology and stratigraphic horizon; sandstone of the Nakataro Mudstone.

Principal benthonic mollusks; *Portlandia watasei* (KANEHARA), *Cyclocardia siogamensis* (NOMURA), *Macoma izurensis* (YOKOYAMA), *Turritella ichishiensis* SHIBATA, *Turritella* sp.

Yamabe Group

SHIIDA and SHIBATA (1968) reported *Cavolinia* sp. which is represented by *Cavolinia* sp. A in this paper from two localities. Locality Yb 1 and locality Yb 2 are equivalent to their locality k1 and locality s2, respectively.

Locality Yb 1. Cliff 350 meters south of Hayama, Tsuge-mura, Yamabe-gun, Nara Prefecture.

Lithology and stratigraphic horizon; sandstone of the Sotonohashi mudstone.

Principal benthonic mollusks; *Acila submirabilis* MAKIYAMA, *Nuculana pennula* (YOKOYAMA), *Yoldia sagittaria* YOKOYAMA, *Lucinoma acutilineatum* (CONRAD), *Macoma izurensis* (YOKOYAMA).

Locality Yb 2. Stream bed of a brook 400 meters southwest of Hayama, Tsuge-mura, Yamabe-gun.

Lithology and stratigraphic horizon; pebble conglomerate of the Sogo sandstone and granule conglomerate.

Principal benthonic mollusks; *Chlamys* sp., *Lucinoma acutilineatum* (CONRAD), *Macoma optiva* (YOKOYAMA), *Turritella sagai* KOTAKA.

Bihoku Group

ITOIGAWA and NISHIKAWA (1976) reported *Cavolinia* sp. which is described in this paper under the name of *Cavolinia* sp. B from the Group. Detailed information on the geographic and stratigraphic positions of the fossil locality and on associated mollusks is provided in their paper.

Fig. 2 indicates the standard sections of the First Setouchi Series in the areas where the fossil localities occur and stratigraphic positions of the localities. Localities Ic 1 and Ic 2 occur in the same horizon in the Ichishi Group. The fossil localities in the Morozaki Group are arranged in ascending order of stratigraphic position as follows; locality Mo 5, locality Mo 4, locality Mo 3, locality Mo 2 and locality Mo 1. They are concentrated in a short interval in the middle portion of the Toyohama Formation except locality Mo 1. Localities Mi 1, Mi 2, Mi 3 and Mi 4 are equivalent or nearly equivalent in stratigraphic position. Locality Mi 5 is slightly lower than these localities. Localities Mi 6, Mi 7 and Mi 8 are stratigraphically equal to one another. The Shukunohora Sandstone in which these three localities occur is unconformably overlain by the Oidawara Formation in which the others lie. As stated before, the pebbles which contain *Vaginella depressa* DAUDIN seem to have been derived from strata which lay in somewhat higher levels than the level of localities Mi 6, Mi 7 and Mi 8. Locality Yb 1 is slightly higher than locality Yb 2. Locality Ay 1 seems to be nearly equal to locality Ay 2.

A general correlation of the First Setouchi Series of these areas except the Chikusa Formation has been accomplished by ITOIGAWA and SHIBATA (1973). Locality Ch 1, locality Yb 1, locality Yg 1 and localities Ay 1 and Ay 2 are roughly correlated with localities Ic 1 and Ic 2. The stratigraphic position of the latter

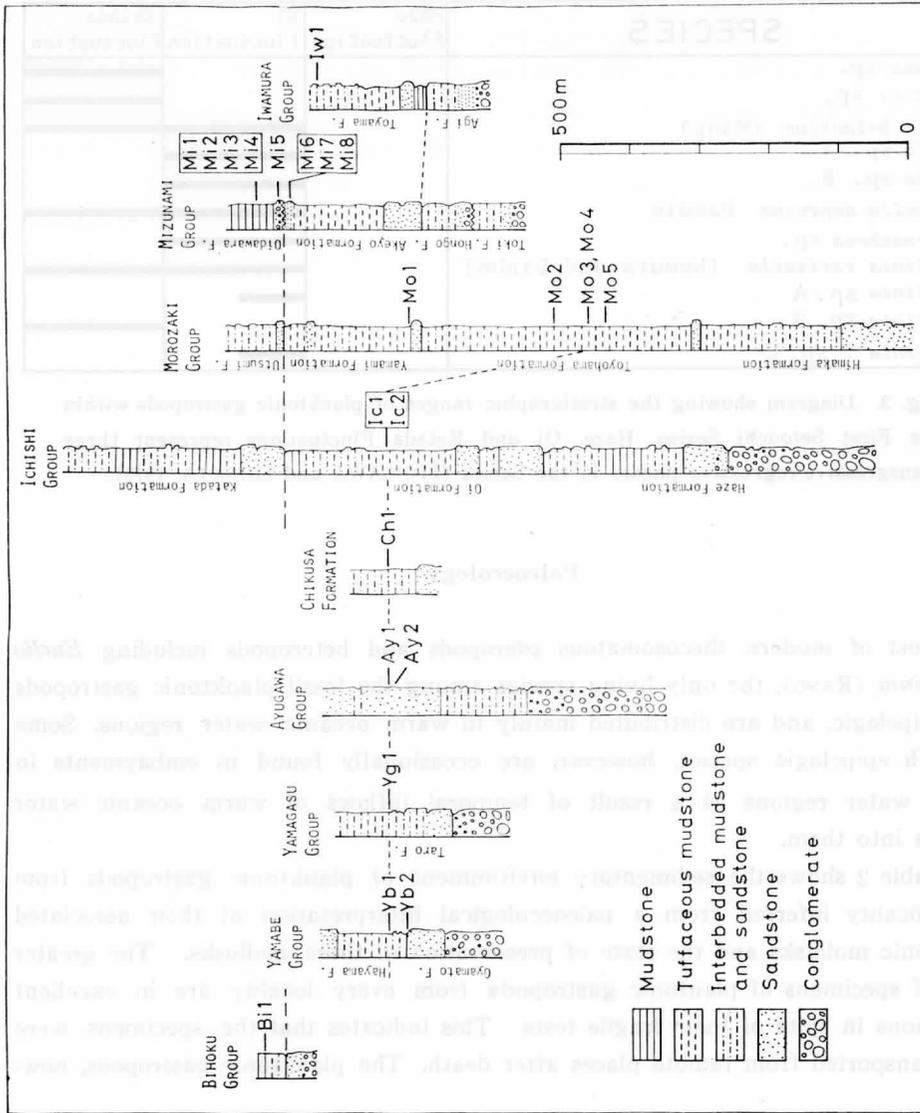


Fig. 2. Stratigraphic correlation diagram of planktonic gastropod-bearing formations in the Setouchi Geologic Province.

seems to correspond to a certain horizon in the short interval between the horizon of locality Mo 2 and that of locality Mo 5. The corresponding position of it in the Mizunami Group appears to be in the lower portion of the Akeyo Formation. On the other hand, the Oidawara Formation is correlated with the Katada Formation of the Ichishi basin. The upper part of the Bihoku Group seems to be correlated with the latter. It is worthy of note that *Miogypsina "kotoi"* HANZAWA and *Operculina complanata japonica* HANZAWA, well-known horizon markers in Japan occur at localities Mi 6, Mi 7 and Mi 8. Fig. 3 indicates the stratigraphic range of each planktonic gastropod. The Haze, Oi and Katada Fluctuations in the figure represent the three minor transgressive-regressive phases in the First Setouchi Series (ITOIGAWA and SHIBATA, 1973).

SPECIES	Haze	Oi	Katada
	Fluctuation	Fluctuation	Fluctuation
<i>Atlanta</i> sp.			
<i>Limacina</i> sp.			
<i>Euclio balantium</i> (Rang.)			
<i>Euclio</i> sp. A			
<i>Euclio</i> sp. B			
<i>Vaginella depressa</i> Daudin			
<i>Bowdenstheca</i> sp.			
<i>Cavolinia raritatis</i> (Nomura and Zinbo)			
<i>Cavolinia</i> sp. A			
<i>Cavolinia</i> sp. B			
<i>Cavolinia</i> ? sp. C			

Fig. 3. Diagram showing the stratigraphic ranges of planktonic gastropods within the First Setouchi Series. Haze, Oi and Katada Fluctuations represent three transgressive-regressive phases in the Series (ITOIGAWA and SHIBATA, 1973).

Paleoecology

Most of modern thecosomatous pteropods and heteropods including *Euclio balantium* (RANG), the only living species among the fossil planktonic gastropods are epipelagic, and are distributed mainly in warm oceanic water regions. Some of such epipelagic species, however, are occasionally found in embayments in warm water regions as a result of temporal inflows of warm oceanic water masses into them.

Table 2 shows the sedimentary environment of planktonic gastropods from each locality inferred from a paleoecological interpretation of their associated benthonic mollusks and the state of preservation of these mollusks. The greater part of specimens of planktonic gastropoda from every locality are in excellent conditions in spite of their fragile tests. This indicates that the specimens were not transported from remote places after death. The planktonic gastropods, how-

Table 2. Environmental conditions of sites of deposition of planktonic gastropods.

Factors \ Localities	Mi 5-8, Ch 1	Yg 1, Yb 1	Iw 1, Mi 1-4
	Ay 1, 2, Yb 2	Bi 1	Mo 1-5, Ic 1, 2
Depth	Shallower than 20-30 m	Between 20-30 and 200 m	Deeper than 200 m
Temperature	Warm	Warm-temperate	Cold
Degree of protection	High	Low	Very low

ever, seem to have not ordinarily lived under such environmental conditions as shown in Table 2 on the basis of the fact that they occur in very limited stratigraphic horizons in each area in spite of the widespread stratigraphic occurrence of assemblages of benthonic mollusks closely similar to those occurring in association with them. It is believed that specimens from localities Ch 1, Ay 1, Ay 2, Yg 1, Yb 1, Yb 2 and Bi 1 lived in shallow water. *Euclio balantium* (RANG), *Euclio* sp. A, *Vaginella depressa* DAUDIN, *Cavolinia raritatis* (NOMURA and ZINBO), *Cavolinia* sp. A and *Cavolinia* sp. B are represented in them. The distribution of these species in shallow water seems to indicate that they are not bathypelagic or mesopelagic forms but are epipelagic ones, if it represents an incidental distribution. Individuals of *Euclio balantium* (RANG), *Euclio* sp. A, *Vaginella depressa* DAUDIN and *Cavolinia raritatis* (NOMURA and ZINBO) from the other localities probably thrived in the upper layer in deep seas, and settled down to bottoms under the influence of cold water after death. The occurrence of *Aturia minoensis* KOBAYASHI at locality Ic 1 and of leaf-remains of warm-temperate land plants at localities Mi 1 and Mi 2 (INA, 1974) may suggest that the upper layers of the depositional sites were made of warm water. Thus, it seems most likely that these species were ordinarily distributed in oceanic water in warm regions, and that likesome of modern epipelagic pteropods they occasionally flowed into sheltered areas together with oceanic water masses.

The remaining planktonic gastropods seem to be similar to these species in ecology on the basis of the fact that they usually occur in association with some of the latter.

Conclusions

Fossils of planktonic gastropods collected from the First Setouchi Series consist of ten species of thecosomatous pteropoda and one species of heteropoda. They all are considered warm water dwelling epipelagic forms. Their occurrence in the Series is limited to several horizons.

Systematic paleontology

All the taxa of planktonic gastropoda from the First Setouchi Series are illustrated in the plate. The following six taxa are described below; *Euclio* sp. A, *Euclio* sp. B, *Bowdenatheca* sp., *Cavolinia* sp. A, *Cavolinia* sp. B and *Cavolinia* ? sp. C. Description of the other taxa is given by ITOIGAWA, SHIBATA and NISHIMOTO (1974). Specimens illustrated herein have been deposited in the Laboratory of Geology, College of General Education, Nagoya University and in the Mizunami Fossil Museum except the specimen of *Cavolinia* sp. B.

Euclio sp. A

(Pl. 13, Figs. 14, 15a, b)

Description:— Shell medium, conical in shape, compressed dorso-ventrally, with distinct transverse folds over surface. Both dorsal and ventral sides very convex, dorsal one with two obscure longitudinal grooves. Hind part not observed. Lateral keels sharp. Aperture oval, angulated at lateral sides.

Dimension:— Width 6.0 mm.

Discussion:— A few fragmentary specimens are available. They have resemblance to specimens of *Euclio balantium* (RANG, 1834) from the Setouchi localities, but differ from the latter in being slenderer and in having more inflated dorsal and ventral sides. The specimen which the author (1970, Pl. 4, Fig. 17) previously illustrated under the name of *Euclio balantium* (RANG) is referred to the present species.

Occurrence:— Localities Ic 1, Ic 2 and Ay 2.

Euclio sp. B

(Pl. 13, Fig. 19)

Discussion:— A single strongly deformed specimen was obtained. It is characterized by its elongated conical shell which narrows down gradually toward embryonic shell, with fine transverse striations on the surface. The above characteristic fits with the description of *Proclio subteres* HUBENDICK, 1951, which according to SPOEL (1962) is synonymous with *Euclio pyramidata antarctica* (DALL, 1908). The specimen, however, is not preserved sufficiently to refer it to the above-mentioned species.

Occurrence:— Locality Mo 5.

Bowdenathea sp.

(Pl. 13, Figs. 7-9)

Description:— Shell small, wedge-shaped, compressed dorso-ventrally, slightly curved dorsally. Ventral side of shell a little more convex than dorsal one. Behind aperture shell faintly constricted in profile view. Lateral edges slightly angulated. Hind part short, pointed. Aperture widened, bean-shaped. Surface smooth with fine growth lines.

Dimension:— Length 10.4 mm and width 4.3 mm.

Discussion:— This species resembles *Bowdenathea jamaicensis* COLLINS, 1934 from the Miocene of Jamaica, but differs from the latter in being larger and in having a faint dorso-ventral constriction behind the aperture.

Occurrence:— Localities Mo 1, Mo 5, Ic 1 and Ic 2.

Cavolinia sp. A

(Pl. 13, Figs. 20-23)

Description: - Shell medium, squat, globular. Dorsal plate of shell moderately inflated, without appreciable longitudinal ribs. Dorsal lip spade-shaped, broadly produced beyond transverse fold, gently curved downward. Ventral plate swollen, with a faint longitudinal ridge on middle portion, external surface sculptured with fine concentric striations. Lateral margins slightly convex. Lateral angles sharp but not produced. Posterior spine short.

Dimension: - Length ca. 10 mm and width ca. 8 mm.

Discussion: - A number of specimens were collected, but they are poorly preserved. This species exhibits some similarity with *Cavolinia tridentata affinis* (D'ORBIGNY, 1836) illustrated by TESCH (1948), but differs from it in having broader dorsal lip. Moreover, they are different from each other in surface sculpture.

Occurrence: - Localities Yb 1 and Yb 2.

Cavolinia sp. B

(Pl. 13, Fig. 13)

Description: - Shell medium size for the genus, subrounded. Dorsal plate somewhat inflated with three longitudinal ribs. Lateral angles obtuse, not produced.

Dimension: - Length 9.1 mm and width ca. 8 mm.

Discussion: - Two poorly preserved specimens were collected by NISHIKAWA. This species resembles *Cavolinia raritatis* (NOMURA and ZINBO, 1935), but it has a more convex dorsal plate.

Occurrence: - Locality Bi 1.

Cavolinia ? sp. C

(Pl. 13, Figs. 24a, b)

Discussion: - A single fragmentary specimen was obtained. It is similar to *Cavolinia inflexa labiata* (D'ORBIGNY) illustrated by TESCH (1946) having a conical posterior portion compressed dorso-ventrally.

Occurrence: - Locality Ic 1.

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Plate

Plate 13

Figs. 1,2. *Limacina* sp.

1. apical view; $\times 3$. Loc. Mi 1. 2. apical view; $\times 3$. Loc. Mi 1.

Figs. 3-6. *Vaginella depressa* DAUDIN

3. a. ventral view; $\times 3$. b. right view, $\times 3$. Loc. Ic 1.

4. a. ventral view; $\times 3$. right view; $\times 3$. Loc. Ic 1.

5. $\times 3$. Loc. Mi 5. 6. $\times 3$. Loc. Mo 2.

Figs. 7-9. *Bowdenatheca* sp.

7. a. ventral view; $\times 3$. b. right view; $\times 3$. c. dorsal view; $\times 3$. Loc. Ic 1.

8. a. ventral view; $\times 2$. b. left view; $\times 2$. Loc. Ic 2.

9. ventral view; $\times 3$. Loc. Ic 1.

Figs. 10-12. *Euclio balantium* (RANG)

10. dorsal view; $\times 2$. Loc. Mo 5. 11. dorsal view; $\times 2$. Loc. Mo 5.

12. ventral view; $\times 2$. Loc. Mo 5.

Fig. 13. *Cavolinia* sp. B.

- dorsal view; $\times 2$. Loc. Bi 1.

Figs. 14,15. *Euclio* sp. A

14. ventral view; $\times 2$. Loc. Ic 2.

15. a. dorsal view; $\times 3$. b. ventral view; $\times 3$. Loc. Ic 1.

Figs. 16-18. *Cavolinia raritatis* (NOMURA and ZINBO)

16. a. ventral view; $\times 3$. b. dorsal view; $\times 3$. Loc. Ic 1.

17. a. ventral view; $\times 3$. b. dorsal view; $\times 3$. Loc. Ic 2.

18. ventral view; $\times 2$. Loc. Mi 1.

Fig. 19. *Euclio* sp. B

- $\times 2$. Loc. Mo 5.

Figs. 20-23. *Cavolinia* sp. A

20. a. dorsal view; $\times 2$. b. ventral view; $\times 2$. c. left view; $\times 2$. Loc. Yb 1.

21. dorsal view; $\times 2$. Loc. Yb 1.

22. a. dorsal view; $\times 2$. b. left view; $\times 2$. Loc. Yb 1.

23. ventral view; $\times 2$. Loc. Yb 1.

Fig. 24. *Cavolinia* ? sp. C

- a. dorsal view; $\times 3$. b. ventral view; $\times 3$. Loc. Ic 1.

Fig. 25. *Atlanta* sp.

- $\times 2$. Loc. Mi 1.



1



2



3a



3b



4a



4b



5



6



7a



7b



7c



8a



8b



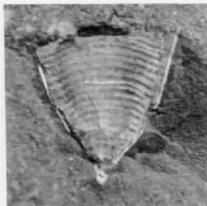
9



10



11



12



13



14



15a



15b



16a



16b



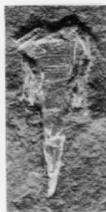
17a



17b



18



19



20a



20b



20c



21



22a



22b



23



24a



24b



25