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Pteropods from the Miocene Fuganji Mudstone Member of Waji, Tottori Prefecture, Japan

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Abstract

A pteropod fauna consisting of nine species is reported and described from the upper part of the Fuganji Mudstone Member of Waji, Tottori Prefecture. It closely resembles those of the early middle Miocene Takakura Formation of the Katsuta Group, Okayama Prefecture and Upper Shale Member of the Bihoku Group, Hiroshima Prefecture.

The occurrence of the pteropods indicates inflows of a warm oceanic water into the depositional site during deposition of the upper part of the Fuganji Mudstone Member.

Introduction

One of the authors, Murata discovered pteropodous molluscs from the Miocene Fuganji Mudstone Member of the Tottori Group at the bank of the Waji River about 1 km east of Waji, Tottori Prefecture in the autumun of 1987. Subsequent collecting in the Fuganji Mudstone of the Waji area by the authors, especially Murata has revealed three additional localities where pteropods occur, and has yielded large pteropod collections from the four localities. All pteropod specimens are moulds and casts. Nine pteropodous species are represented in the collections. In addition one heteropodous species was found at one of these localities. The greater part of these pelagic molluscs, however, remain unnamed owing to the ill state of preservation of their specimens. This paper describes pelagic molluscs from these localities, and mentions the age and sedimentary environment of the pteropod-bearing strata. There is no published study on the pteropod fauna of the Tottori Group.

All specimens treated in this paper except those illustrated and measured are deposited in Faculty of Education, Tottori University. Of the illustrated and measured specimens one of the illustrated specimens of *Clio carinata* is in the Tottori Prefectural Museum, and the remaining specimens are deposited in College of General Education, Nagoya University.

We thanks Mr. Kiyoharu Hoshimi of the Tottori Prefectural Museum who allowed us to examine pteropod specimens in the Tottori Prefectural Museum collection, and helped us in the field investigation.

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Stratigraphy

The early to middle Miocene Tottori Group (Murayama and others, 1963) is extensively exposed in the eastern part of Tottori Prefecture. Many workers including Nishiwaki and Imamura (1956), Uemura and others (1979), Matsumoto (1986, 1991) and the Tottori Green Tuff Research Group (1989) proposed stratigraphic classifications of the group more or less different from one another. So far as the stratigraphy of this area is concerned, however, there is no remarkable difference among previous studies. This report has followed the classification and nomenclature of Uemura and others who stratigraphically mapped the Wakasa district in detail.

The Fuganji Mudstone Member consists chiefly of mudstones. It is more than 400 m in total thickness. The lower part of the Fuganji Mudstone consists of laminated mudstones and siltstones, and land plant remains are plentiful in them at Fuganji, Okamasu and some other places, being mostly represented by *Metasequoia miocenica, Salix* sp., *Comptonia naumanni, Juglans* sp. and *Liquidamber formosana* (Hojo, 1973), but no fossils of marine organisms have been found in them. From the lithofacies and the fossil content they seem to be lacustrine sediments.

The middle part of the Fuganji Mudstone Member consists of interbedded mudstones and siltstones with intercalations of acidic tuff. Marine fishes such as *Sardinella* and *Osmerus* occur abundantly in its lower part at Miyanoshita, Mitani and Shichiyama in addition to the plants mentioned above. A Japanese living representative of *Osmerus, O. dentex* inhabits a cold water.

The upper part of the member is composed of massive black mudstones intercalated with acidic tuffs and turbidites. Marine molluscs are fairly common in its lower half, but no fossils have been found in its upper half.

Locations of localities from which pteropods were obtained are shown in Fig. 1. The stratigraphic relation of these localities is determinable on the basis of marker tuffs. They

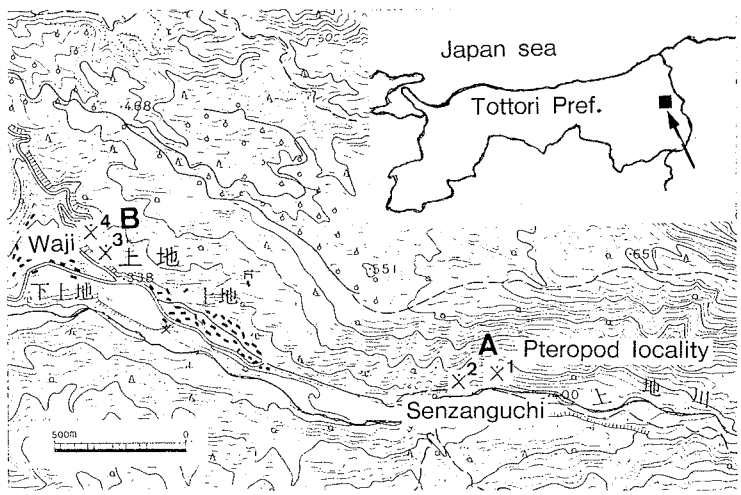

Fig. 1. Locations of pteropod localities in the Waji area, Tottori Prefecture.

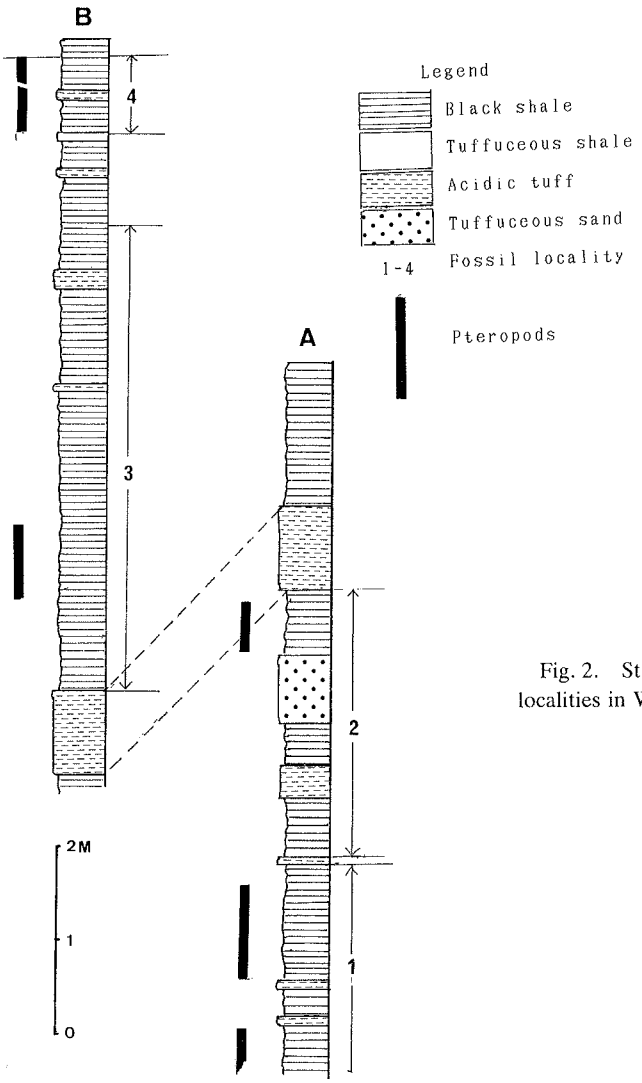

Fig. 2. Stratigraphic sections at the pteropod localities in Waji.

stratigraphically are within a 13 m thick sequence of mudstones and tuffs in the upper part of the Fuganji Mudstone (Fig. 2). This sequence lies about 50 m above the top of the underlying conglomerates exposed in the floor of the Waji River between Kamiarafune and the Waji Bridge.

Age

A checklist of pteropods from Wajii is shown in Table 1. Of the nine species *Vaginella* sp. is the most abundant species.

Seven pteropodous species reported by Shibata and others (1989) from the Takakura Formation of the Katsuta Group, Okayama Prefecture and six species reported by them from

Table 1. Checklist of heteropodous and pteropodous molluscs from the Fuganji Mudstone Member of Waji. R: 1–20, F: 21–50, C: 51–100, A: more than 100 specimens

Species \ Localities	1	2	3	4
Carinaria sp.				R
Limacina sp.			R	C
Hyalocylis sp.				R
? *Vaginella depressa* Daudin	R		R	F
V. sp.	A	R	R	A
Clio carinata Audenino			R	R
? *C. distefanoi* Checchia-Rispoli	R	R	R	R
C. itoigawai (Shibata)	A	R	R	R
Cuvierina sp.	R	R	R	R
Cavolinia bisulcata (Kittl)	R		R	F

the Upper Shale Member of the Bihoku Group, Hiroshima Prpefecture are included in the pteropod fauna, and *Vaginella* sp. is the dominant species in the both formations. This close faunal resemblance suggests that pteropod-bearing strata of the three areas are synchronous. The pteropod-bearing strata in the Takakura Formation and the Upper Shale Member occur in the upper part of the *Amphicoryna scalaris-Ubigerina crassicoststa* zonule of Tai (1959) (Shibata and others, 1989), the upper boundary of which agrees with the boundary between the planktonic foraminiferal zones N9 and N10 of Blow (1969) (Tai, 1985). The pteropod-bearing strata of this area thus seem to be assigned to the N9 zone in age. A similar pteropod fauna characterized by the predominance of *Vaginella* sp. occurs in the Konoura Shale Member of Uchiura Group, Fukui Prefecture (Shibata and Ujihara, 1990). Nakagawa and others (1985) suggested the lower part of the N9 zone for the Konoura Shale. It seems to support the aforementioned age assignment for the pteropod-bearing strata of Waji.

Tai (1959) reported the same benthic foraminiferal zonule as the pteropod-bearing strata in the Takakura Formation and the Upper Shale Member from the Fuganji Mudstone of Waji. As he gave no locality data for his sampling sites, their stratigraphic relation with our pteropod localities is unknown.

Paleoenvironment

Cavolinia bisulcata occurs in the early to middle Miocene Mizunami Group of Gifu Prefecture in association with such tropical, shallow sea, benthic molluscs as *Terebralia* sp., *Chelyconus* sp. and *Noditerebra osawanoensis* (Itoigawa and others, 1981). It suggests that the pteropodous species is an inhabitant of a warm water, and the other pteropodous species which occur associated with it in the Fuganji Mudstone Member seem to be also warm water species.

Table 2 shows a checklist of benthic molluscs collected from the pteropod localities. Dominant species by locality are as follows: locality 1; *Limopsis* sp. and *Limatula* sp. localities 2 and 3; *Propeamussium fuganjiensis* and *Delectopecten peckhami* and locality 4; *Lamellinucula* sp. and *Propeamussium* sp. These dominant species are considered to be bathyal species. The

Table 2. Checklist of benthic moluscs from the pteropod localities in Waji

Species \ Localities	1	2	3	4
Acharax tokunagai (Yokoyama)	*	*	*	
Lamellinucula sp.	*			*
Acila sp.	*			
Malletia sp.	*			
Yoldia sp.	*			
Portlandia sp.	*			
Limopsis sp.	*	*		*
Propeamussium tateiwai Kanehara	*			
P. fuganjiensis Omori and Inoue (MS)	*	*	*	
P. sp.				*
Delectopecten peckhami (Gabb)	*	*	*	*
Limatula sp.	*	*		
Lucinoma acutilineatum (Conrad)	*		*	
Leukomoides cf. *nipponicus* (Ogasawara)	*			
Paphia sp.	*			
Thracia sp.	*			
Dentalium sp.	*			
Fissidentalium cf. *yokoyamai* (Makiyama)	*	*	*	
Phos sp.				*

associated benthic molluscs suggest batyal depths as the depth of deposition for the pteropod-bearing strata. On the basis of the associated benthic molluscan fauna Matsumoto (1986) suggested that the middle to upper part of the Fuganji Mudstone Member was deposited in a cold water. The occurrence of pteropods from it, however, indicates that the surface layer of the sea of the depositional site was subject to a warm water during deposition of the upper part of the member, though the bottom layer of the sea of the assumed depths was naturally filled with a cold water.

Systematic descriptions

Phylum Mollusca
Subphylum Conchifera
Class Gastropoda
Subclass Prosobranchia
Order Mesogastropoda
Superfamily Atlantacea
Family Carinariidae
Genus *Carinaria* Lamarck, 1801

Carinaria sp.
(Pl. 1, Figs. 1–2)

Material: Two imperfect specimens.

Description: Shell small, hoodlike, with a carina; apex coiled back, situated a little posterior of the posterior end of aperture of the shell standing on the aperture in side view. Greatest height of the shell slightly smaller than the length of the aperture. Carina well developed, about 1/4 as broad as the length of the aperture near the aperture. Embryonic shell consisting of about three whorls, small, helicinoid; the remaining part of the shell transversely plicated; plications narrower than their interspaces, slightly curved downward, continuing along the carina turning upward; about 18 primary plications some of which are bipartite and a few secondary ones one an adult specimen.

Measurement (in mm):

	Greatest height	Length of aperture
(Figured specimen)	8.0	8.5
(〃)	3.0	4.0

Comparison: This species resembles *C. paretoi* Mayer from the Langhian of Italy in outline, but the shell is less depressed and transverse plicae are less crowded. *C.* n. sp. Stancu from the upper Bandenian of Romania seems to be allied to this species, but the specimens figured are too poorly preserved for detailed comparison. *C.* sp. from this area differs from the Recent *C. lamarcki* (Peron and Lesueur) in the higher shell and the higher carina.

Occurrence: Locality 4.

Subclass Opisthobranchia
Order Thecosomata
Suborder Euthecosomata
Family Limacinidae
Genus *Limacina* Bosc, 1817

Limacina sp.
(Pl. 1, Figs. 3, 4)

Limacina sp. Shibata, Taguchi and Ujihara, 1989, p. 34, pl. 4, figs. 1–3.

Material: 53 axially compressed inner moulds.

Description: Shell very small, largest specimen being 2.2 mm in width, sinistral. Whorls about four and a half, rather rapidly enlarging. Spire seems to project from the outer whorl in side view, forming a low cone. Suture deeply impressed. Surface smooth. Umbilicus deep and broad.

Measurement (in mm):

	Width
(Figured specimen)	2
(〃)	2

Comparison: From the similarity of the size, the mode of enlargement of whorls and the shape of umbilicus this small Limacina seems to be conspecific with *Limacina* sp. described by Shibata and others (1989) from the middle Miocene Takakura Formation of the Katsuta Group, Okayama Prefecture and the Upper Shale Member of the Bihoku Group, Hiroshima Prefecture. *L.* sp. resembles *L. valvatina* (Reuss) from the Miocene of Poland in apical view, but the umbilicus is broader. Available specimens are insufficiently preserved for specific determination.

Occurrence: Localities 3 and 4.

Family Cavoliniidae
Subfamily Clionae
Ganus *Hyalocylis* Fol, 1875

Hyalocylis sp.
(Plate 1, Fig. 5)

Material: Two transversely compressed specimens.

Description: Shell small, conical, annulated; apical angle about 30°. Lateral profiles faintly convex. Annulations fine, a little narrower than their interspaces, becoming more closely spaced toward the apex, about 40 in total, numbering in 13 in 2 mm length of the middle part of the shell. Apex seems to be bulbous. Length 5.6 mm, diameter 2.4 mm (figured specimen).

Remarks: This species closely resembles the Recent *H. striata* (Rang) and *H. haitensis* Collins from the Miocene of Haiti, but annulations are much finer and greater in number. *H.* sp. somewhate resembles *Praehyalocylis annulata* (Tate) from the Eocene of Australia in surface sculpture, but the shell is smaller and faintly convex conical in outline, and the apex appears to be bulbous. This species is probably unnamed species, but available specimens are not good enough for type specimens.

Occurrence: Locality 4.

Genus *Vaginella* Daudin, 1800

? *Vaginella depressa* Daudin, 1800
(Pl. 1, Fig. 6)

Vaginella depressa Daudin, 1800, p. 145, pl. 11, fig. 1; Basterot, 1825, p. 19, pl. 4, fig. 16;

Bellardi, 1873, p. 64; Tiberi, 1880, p. 37; Kittl, 1886, p. 57, pl. 2, figs. 17–22; Benoist, 1889, p. 28, pl. 2, fig. 4a–c; Audenino, 1897, p. 108; Sacco, 1904, p. 15, pl. 4, fig. 10; Bellini, 1905, p. 40; Checchia-Rispoli, 1921, p. 15, fig. 6; Zilch (in Wenz), 1959, p. 51, fig. 170; Sirna, 1968, p. 424, fig. 12; Ctyroky, Papp and Steininger, 1968, p. 132, pl. 4, figs. 1, 2; Shibata, 1970, pl. 4, figs. 13a, b; Robba, 1971, p. 89, pl. 4, figs. 6, 7; Robba, 1972, p. 502, pl. 59, fig. 12, pl. 60, fig. 8; Shibata (in Itoigawa, Shibata and Nishimoto), 1974, p. 191, pl. 60, figs. 9, 10; Shibata, 1977, pl. 13, figs. 3–6; Shibata, 1980, pl. 3, figs. 13–17; Itoigawa, Shibata, Nishimoto and Okumura, 1981, pl. 47, figs. 6, 7; Itoigawa, Shibata, Nishimoto and Okumura, 1982, p. 295; Ujihara and Shibata, 1982; pl. 6, fig. 21; Spano, 1983, p. 257, pl. 16, fig. 9, p. 17, figs. 1–7, pl. 18, figs. 1–5; Shibata, 1983, p. 77, pl. 2, figs. 7, 8; Janssen, 1984a, p. 75, pl. 3, fig. 11, pl. 4, figs. 9–13; Japanese, 1984b, figs. 10–13; Janssen, 1986, fig. 5; Shibata and Ujihara, 1989, p. 25, pl. 1, figs. 1–3; Janssen, 1989, p. 51, pl. 7, figs. 8–12, pl. 8, figs. 1–8; Shibata, Taguchi and Ujihara, 1989, p. 35, pl. 4, figs. 4, 5.

Material: 28 transversely compressed specimens.

Description: Shell small, bottle-shaped. Greatest transverse diameter situated at about the middle of the shell, from this point the shell rapidly tapering posteriorly. Lateral keels distinct in the posterior part of the shell. Post-apertural constriction of the shell faint. Apertural rims convex. Apex sharp. Apical angle about 40°. Length 6.0 mm, width 2.4 mm (figured specimen).

Remarks: All available specimens are poorly preserved. They resemble *V. depressa* Daudin in general outline and size, though they appear to be somewhat slenderer. The specimens are questionably assigned to *V. depressa*.

Occurrence: Localities 1, 3 and 4.

Vaginella sp.
(Pl. 1, Figs. 7–10)

Vaginella sp. Shibata, Taguchi and Ujihara, 1989, p. 36, pl. 4, figs. 9–12.

Material: More than 1700 specimens were collected from Waji. All specimens are transversely flattened.

Description: Shell large, slender, tapering convexly toward a pointed apex, with a well defined keel on each side of the shell. Both dorsal and ventral profiles gently convex, greatest dorso-ventral diameter being situated at about the middle of the shell length. Post-apertural constriction of the shell slight. Dorsal and ventral apertural rims convex. Embryonic shell bulged, constricted anteriorly; tip pointed. Exterior smooth. Apical angle about 20°.

Measurement (in mm):

	Length	Width
(Figured specimen)	14.3	3.7
(〃)	11.4	3.5
(〃)	11.3	—
	14.5	3.7
	14.0	3.5
	13.9	3.8
	11.3	3.4

Remarks: This species closely resembles *V. austriaca* Kittl from the Miocene of Austria, but is larger and slenderer. It also resembles *V. aucklandica* Clarke from the Miocene of New Zealand, but its aperture is wider and seems to be elongated elliptical.

V. sp is the most common pteropodous species in the Waji area. It occurs widely in the early middle Miocene of the Chugoku and San'in regions including this area. Numerous specimens are available from these regions, but they all are casts and are strongly compressed transversely. Better material must be available in order to make definite specific identification.

Shibata and others (1989) suggested that this species serves as a good indicator of the N9 zone.

Occurrence: Localities 1–4.

Genus *Clio* Linnaeus, 1767

Clio carinata Audenino, 1897

(Pl. 1, Figs. 11, 12)

Clio carinata Audenino, 1897, p. 102, pl. 5, fig. 3; Dieci, 1961, p. 41, pl. 15, fig. 5, pl. 16, fig. 8; Robba, 1971, p. 81, pl. 2, fig. 17, pl. 3, figs. 1–3; Stancu, 1974, p. 186, pl. 3, fig. 10; Robba and Spano, 1978, p. 772, pl. 80, fig. 4; Shibata and Ujihara, 1989, p. 29, pl. 3, figs. 3, 4; Shibata, Taguchi and Ujihara, p. 37, pl. 4, figs. 15, 16.

Balantium (*Flabellulum*) *carinatum* (Audenino), bellini, p. 39, figs. 40, 41.

Material: Two imperfect specimens collected by us from locality 4 and one outer mould of the dorsal side in the Tottori Prefectural Museum collection from locality 3.

Description: Shell small, rhombic, nearly as wide as long. Lateral margins slightly diverging, prolonged anteriorly, forming a short lateral spine. Dorsal side marked with longitudinal ribs and transverse folds; longitudinal ribs five, a broad, prominent rib in the median part and two narrow, low ribs on each side of the median rib, inner lateral ones running close by the median one, converging posteriorly; transverse folds curved, their convex side looking toward aperture, narrower than their interspaces; ventral side with a prominent, bipartite, median longitudinal rib, a narrow longitudinal rib on each side of the median longitudinal rib and

transverse folds in flattened areas between the median longitudinal rib and the lateral margins; in addition faint longitudinal striations are visible on the median part of either side. Aperture wide; apertural rims convex. Embryonic shell bulbous. Apical angle about 45°.

Measurement (in mm):

	Length	Width
(Figured specimen)	13.0	12.6
(〃)	6.1	5.5

Remarks: This species is characterized by the slightly concave lateral margins, the bipartite, median longitudinal rib on the ventral side and the strongly curved transverse folds on the dorsal side.

Reported Japanese occurrences of *C. carinata* are from the Shimosato Sandstone and Siltstone of the Kumano Group, Wakayama Prefecture and the Takakura Formation of the Katsuta Group. The Shimosaro Sandstone and Siltstone is assigned to the N8 zone, and the Takakura Formation is to the N9 zone. It has been known from the Langhian and the Serravallian in Europe.

Occurrence: Localities 1 and 2.

? *Clio distefanoi* Checchia-Rispoli, 1921
(Pl. 1, Figs. 13, 14)

Clio (*Clio*) *distefanoi* Checchia-Rispoli, 1921, p. 20, fig. 10.
Clio distefanoi Checchia-Rispoli; Sirna, 1968, p. 421, fig. 7; Robba, 1971, p. 82, pl. 3, figs. 4–6; Robba and Spano, 1978, p. 773, pl. 79, figs. 1, 2; D'Alessandro, Laviano, Ricchetti and Sardella, 1979, p. 84, pl. 16, figs. 55–61; D'Alessandro and Robba, 1981, p. 636, pl. 70, figs. 1–5.
Clio sp. Shibata, Taguchi and Ujihara, 1989, p. 38, pl. 4, figs. 4–6.

Material: 12 poorly preserved specimens.

Description: Shell small, trigonal, with apical angle of about 25°. Lateral margins nearly straight, keeled and compressed. Ventral side flattish, with a low, median longitudinal ridge, which is a little broader than 1/3 of the shell width near aperture; areas between the longitudinal ridge and the lateral margins flattened, curved ventrally near the margins. Dorsal side seems to be swollen, but details are unknown owing to the poor preservation of the specimens. Exterior smooth.

Measurement (in mm):

	Length	Width
(Figured specimen)	10.0	5.0
(〃)	12.0	6.5

Remarks: The shell outline and the features of the ventral side of this spccies agree with those of *C. distefanoi* Checcia-Rispoli from the Miocene of Italy. Well preserved material must be available for positive determination of the specific name. This species differs from *C. garganica* Sirna from the same Miocene that *C. distefanoi* was originally described from in the larger apical angle. Comparison with the specimens of *C.* sp. described by Shibata and others (1989) from the Bihoku and Katsuta Groups shows the Waji specimens are conspecific with those from the two groups.

Occurrence: Localities 1–4.

Clio itoigawai (Shibata, 1983)
(Pl. 1, Figs. 15, 16)

Euclio balantium (Rang) (non Rang, 1834), Shibata, 1970, p. 81, pl. 4, figs. 16, 17; Shibata (in Itoigawa, Shibata and Nishimoto), 1974, p. 192, pl. 60, fig. 4; Shibata, 1977, pl. 13, figs. 10–12.

Euclio cf. *balantium* (Rang); Itoigawa, Shibata, Nishimoto and Okumura, 1981, pl. 47, figs. 8–10; Itoigawa, Shibata, Nishimoto and Okumura, 1982, p. 296.

Euclio itoigawai Shibata, 1983, p. 73, pl. 2, figs. 1–3.

Clio itoigawai (Shibata); Shibata, Ishigaki and Ujihara, 1986, p. 46, pl. 7, fig. 7; Shibata, Taguchi and Ujihara, 1989, p. 38, pl. 4, figs. 13, 14.

Material: More than 100 specimens were obtained from this area. Most of them are incomplete and are deformed.

Description: Shell triangular, slightly curved dorsally in the posterior part. Lateral ribs slightly diverging in the posterior part, faintly converging in the anterior part, double, gutter-shaped in the anterior part. Cross-section near the apex round. Sculpture consisting of longitudinal ridges and transverse folds; longitudinal rigdes on the dorsal side three, of which the median one is the narrowest, converging posteriorly, broader than their interspaces; a broad longitudinal ridge present in the median part of the dorsal side, the breadth of the ridge about a half of that of the shell near aperture, areas between the longitudinal ridge and lateral margins flattened; transverse folds closely spaced, curved, their convex side looking toward the aperture. Aperture lip-shaped. Apical angle about 60°.

Measurement (in mm):

	Length	Width
(Figured specimen)	16.8	9.5
(〃)	11.4	9.0

Remarks: This species is closely allied to the living *C. recurva* (Children), but the shell is smaller, transverse folds are finer and more closely spaced, and the median longitudinal ridge on the dorsal side is narrower than the lateral ones. It somewhat resembles *C. guidotti*

Simonelli from the Miocene of Italy, but the aperture is narrower, and transverse folds are finer.

C. itoigawai has a bio-chronological range of the N8 zone to the N10/12 zone, occurring most commonly in the N8 and N9 zones.

Occurrence: Localities 1–4.

Subfamily Cuvierininae
Genus *Cuvierina* boas, 1886

Cuvierina sp.
(Pl. 1, Figs. 17–19)

Material: 28 transversely compressed specimens.

Description: Shell large, largest specimen reaching 18 mm in length including a part of juvenile spine, bottle-shaped, slightly bulging in the middle part; posterior end of permanent shell closed by a convex septum. Greatest diameter situated at about the middle of the shell from which the juvenile spine is excluded. Below the aperture the shell slightly constricted in frontal view. Surface smooth.

Measurement (in mm):

	Length	Width
(Figured specimen)	11.5	3.1
(〃)	13.9	4.6
(〃)	17.8	4.3

Comparison: This species most closely resembles *C. grandis* D'Alessandro and Robba from the Miocene of Italy, but the post apertural constriction is stronger. It more or less resembles the living *C. columnella* f. *columnella* (Rang), but the shell is larger and its greatest diameter is situated more anteriorly. *C.* sp. from this area differs from *C.* sp. described by Shibata and Ujihara (1989) from the Miocene Kumano Group of Wakayama Prefecture in that the posterior half of the shell is more strongly bulged.

Occurrence: Localities 1–4.

Subfamily Cavoliniidae
Genus *Cavolinia* Abildgaard, 1791

Cavolinia bisulcata (Kittl, 1886)
(Pl. 1, Figs. 20–22)

Hyalaea bisulcata Kittl, 1886, p. 65, pl. 2, figs. 29–32; Janssen, 1984a, p. 68, pl. 5, figs. 6–8.
Cavolinia cf. *bisulcata* Kittl, Audenino, 1897, p. 101, pl. 5, fig. 2.

Cavolinia audeninoi Vinassa de Regny, 1898, p. 84; Bellini, 1905, p. 34, figs. 21, 22; Robba and Spano, 1978, p. 778, pl. 76, fig. 9, pl. 80, fig. 1, pl. 81, fig. 5; D'Alessandro and Robba, 1981, p. 651, pl. 75, figs. 1–4, pl. 76, figs. 1, 2.

Cavolinia audeninoi var. *bononiensis* Vinassa de Regny, 1898, p. 84, fig.

Cavolinia cerullii Checchia-Rispoli, 1921, p. 24, fig. 11; Sirna, p. 428, fig. 19; obba, 1977, p. 612, pl. 25, figs. 5–7; D'Alessandro, Laviano, Ricchetti and Sardella, 1979, p. 91, pl. 15, figs. 16, 17, 23, 28.

Cavolinia audeninoi trinitatis Rutsch, 1934, p. 311, pl. 8, figs. 6–8.

Cavolina raritatis Nomura and Zinbo, 1935, p. 169, pl. 15, figs. 25, 26.

Cavolinia cf. *raritatis* (Nomura and Zinbo), Shibata, 1970, pl. 4, figs. 14, 15; Shibata (in Itoigawa, Shibata and Nishimoto, 1974, p. 192, pl. 60, figs. 5–8, 12.

Cavolina (*Cavolina*) audeninoi (Vinassa de Regny), Robba, 1971, p. 100, pl. 4, fig. 15, pl. 5, figs. 1–5.

Cavolinia raritatis (Nomura and Zinbo), Shibata, 1977, pl. 13, figs. 16–18; Shibata, 1980, pl. 3, figs. 19–21; Itoigawa, Shibata, Nishimoto and Okumura, 1981, pl. 47, figs. 12–15; Itoigawa, Shibata, Nishimoto and Okumura, 1982, p. 296; Ujihara and Shibata, 1982, pl. 6, fig. 22; Shibata, 1983, p. 81, pl. 2, fig. 13.

Cavolinia bisulcata (Kittl), Shibata, Ishigaki and Ujihara, 1986, p. 49, pl. 8, figs. 12, 13; Ujihara, Shibata and Saito, 1990, p. 319, pl. 2, fig. 7.

Cavolinia bisulcata var. *raritatis* (Nomura and Zinbo); Shibata and Ujihara, 1989, p. 32, pl. 3, figs. 6–8; Shibata, Taguchi and Ujihara, 1989, p. 39, pl. 4, figs. 17–19.

Material: 55 poorly preserved specimens.

Description: Shell small, lateral margins rounded. Ventral side as long as wide, inflated, with two radiating grooves and faint transverse undulations; ventral lip sharp, not recurved. Dorsal side longer than wide, slightly inflated in the median part, provided with three, very low, longitudinal ridges which converge posteriorly and concentric undulations; dorsal lip slightly bent ventrally, projected far beyond the rim of the ventral lip. Posterior spine small. Lateral spines not well developed.

Measurement (in mm):

	Length	Width
(Figured specimen; dorsal plate)	12.3	8.0
(〃 ; ventral plate)	8.3	8.8
(〃 ; 〃)	4.3	5.5

Remarks: Dorsal longitudinal ridges of specimens from the Fuganji Mudstone are lower than those of the lectotype and para-lectotype of *C. bisulcata* (Kittl) figured by Janssen (1984a, pl. 5, figs. 4 and 5). Shibata and Ujihara (1989) discriminated Japanese Miocene specimens with which the Fuganji specimens are identical from *bisulcata,* and identified them with *C. raritatis* (Nomura and Zinbo) from the Miocene Yanagawa Shell Bed of Fukushima Prefecture, placing *raritatis* in the rank of the variety of *bisulcata.* The difference mentioned above,

however, may fall within the variation of *bisulcata*.

One (Shibata) of the authors recently examined four topotypes of *raritatis* and 12 specimens of it from the Yanagawa Shell Bed near the type locality. All the specimens have prominent longitudinal ribs on their dorsal side, and thus *raritatis* seems to be a synonym of *bisulcata*.

Occurrence: Localities 1, 3 and 4.

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Plate 1

Figs. 1, 2. *Carinaria* sp. Loc. 4. 1a, inner cast, ×3; 1b, outer mould, ×3; 2, inner cast, ×6.

Figs. 3, 4. *Limacina* sp. Loc. 4. 3, apical view, ×15; 4, umbilical view, ×11.

Fig. 5. *Hyalocylis* sp. Loc. 4. ×6.1.

Fig. 6. ? *Vaginella depressa* Daudin Loc. 4. ×5.

Figs. 7–10. *Vaginella* sp. 7–9, loc. 1, ×3; 10, loc. 4, ×15.

Figs. 11, 12. *Clio carinata* Audenino 11, dorsal view, loc. 3, outer mould, ×3; 12, ventral view, loc. 4, inner cast, ×3.

Figs. 13, 14. ? *Clio distefanoi* Checcia-Rispoli Loc. 1. Ventral view. 13, ×3.5; 14, ×3.

Figs. 15, 16. *Clio itoigawai* (Shibata) Loc. 1. 15, dorsal view, ×2.4; 16, ventral view, ×3.

Figs. 17–19. *Cuvierina* sp. 17, 18, loc. 1, ×3; 19, loc. 4, ×2.

Figs. 20–22. *Cavolinia bisulcata* (Kittl) Loc. 1. 20, dorsal view view, ×2.2; 21, ventral view, ×2.8; 22, ventral view, ×4.

Plate 1