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Pelagic Mollusks from the middle Pleistocene Takamatsu Silty Sandstone of the Atsumi Group in the Atsumi Peninsula, central Japan

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渥美半島の渥美層群高松シルト質砂岩（中期更新世）産浮遊性貝類

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(Abstract)

Three heteropods and fifteen pteropods are described from the middle Pleistocene Takamatsu Silty Sandstone of the Atsumi Group in the Atsumi Peninsula, Aichi Prefecture. They all are living species, and are inhabitants of warm open sea water. The presence of pelagic mollusks in all the samples from the sequence between the *Mya* and *Tonna* Beds indicates that open sea water frequently or continuously flowed into the depositional site during deposition of the sequence. Their absence in the sample from the *Dosinia* Bed suggests no inflow of open sea water into it in the course of deposition of this bed.

Introduction

The middle Pleistocene Takamatsu Silty Sandstone of the Atsumi Group in the Atsumi Peninsula, Aichi Prefecture is well known for its prolific molluscan fossils (Yokoyama, 1926; Oinomikado, 1933; Hayasaka, 1961). Shibata and Ujihara (1983) reported two pteropodous species from the Takamatsu Silty Sandstone. Recently we made pelagic mollusk collecting from it again. As a result a lot of heteropod and pteropod specimens were obtained. They consist of three species of heteropods and fifteen species of pteropods including the two species previously reported from it. The purpose of this paper is to describe all the heteropods and pteropods from that member, and to interpret their paleoenvironmental significance.

All specimens treated in this paper are housed in Graduate School of Environmental Studies, Nagoya

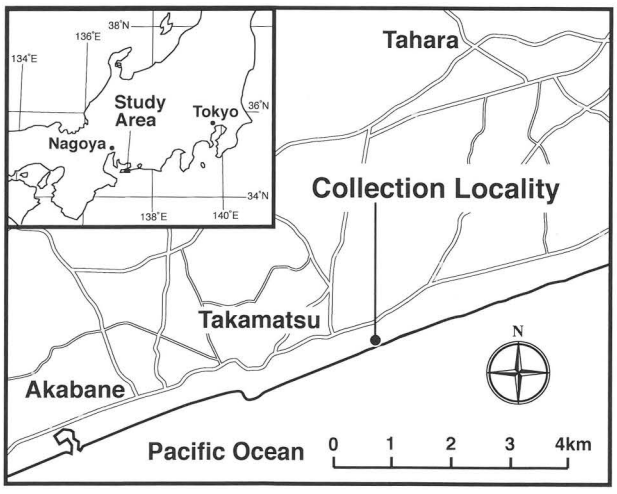

Fig. 1. Map showing the collecting locality of pelagic mollusks from the Takamatsu Silty Sandstone at Takamatsu, Tahara City, Aichi Prefecture.

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University.

Collecting locality and age

The stratigraphy of the Atsumi Group has been described by many workers including Oinomikado (1933), Kuroda (1958), Hayasaka (1961), Hiroki and Kimiya (1990), Sugiyama (1991) and Shimamoto and others (1994). This paper follows Shimamoto and others for the classification and nomenclature of the group. The collection of pelagic mollusks was made at the exposure of the Takamatsu Silty Sandstone 600m southeast of Takamatsu, Tahara City (Fig. 1). This locality is the same locality as locality A1 of Shibata and Ujihara (1983). Sampling for pelagic mollusks was made at eight horizons in the stratigraphic sequence between the *Dosinia* and *Tonna* Beds (Oinomikado, 1933) (Fig. 2). Sample 1, the stratigraphically lowest sample is from the *Dosinia* Bed, and the others are from the sequence between the *Mya* and *Tonna* Beds. Two kg of sediment was collected from each sampling horizon. Besides that, additional 20 kg of sediment was sampled for collecting rare pelagic mollusks from horizon 7 where pelagic mollusks most abundantly occur. Pelagic mollusks were found to occur in all the samples except sample 1 (Table 1).

Shimamoto and others (1994) dated the Takamatsu Silty Sandstone to 0.44 ± 0.18 Ma on the basis of the ESR-dating measurement.

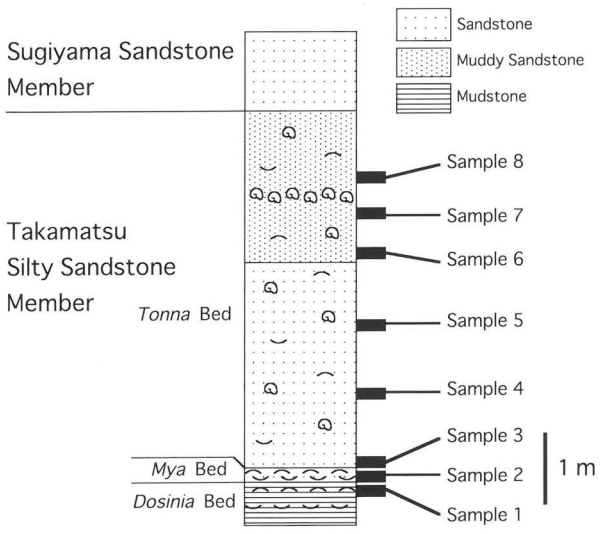

Fig. 2. Columnar section of the Takamatsu Silty Sandstone at the collecting locality with the horizons sampled for pelagic mollusks.

Species / Sample Numbers	1	2	3	4	5	6	7	8
Atlanta peroni Lesueur				1			4	
A. lesueuri Souleyet							(1)	
A. turriculata d'Orbigny							(4)	
Limacina inflata (d'Orbigny)			5	1	1	2	94	12
L. lesueurii (d'Orbigny)			2	1	2	1	35	16
L. bulimoides (d'Orbigny)							2	4
L. trochiformis (d'Orbigny)			5	4	4	8	55	23
Creseis acicula (Rang)		2	15	6	10	12	255	24
C. virgula (Rang)		1	47	11	30	20	800	43
Styliola subula (Quoy and Gaimard)			1	1			8	1
Hyalocylis striata (Rang)			1	1		1	49	1
Clio pyramidata Linnaeus							3	1
Cuvierina columnella (Rang)							(1)	
Diacria trispinosa (de Blainville)							(2)	
D. quadridentata (de Blainville)							5	1
Cavolinia globulosa (Gray)							(1)	
C. inflexa (Lesueur)			2				2	
Diacavolinia longirostris (de Blainville)							(10)	

Table 1. List of heteropods and pteropods from the Takamatsu Silty Sandstone at Takamatsu.
Numbers in parentheses show individual numbers of heteropods and pteropods found restrictedly in the additional sample.

Paleoenvironment

Hayasaka (1961) suggested shallow marine water in a sheltered embayment and relatively deeper marine water in an embayment widely open seawards as the sedimentary environment for the *Dosinia* Bed and both the *Mya* and *Tonna* Beds, respectively on the basis of benthic mollusks.

All the heteropods and pteropods from the Takamatsu Silty Sandstone are living forms inhabiting warm oceanic water regions (Tesch, 1946; Tesch, 1948; Spoel, 1967; Bé and Gilmer, 1977), and they are useful as indicators of warm oceanic waters. The presence of such pelagic mollusks in samples 2 to 8 indicates frequent or continuous inflowing of warm open sea water into the depositional site during deposition of the sequence between the *Mya* and *Tonna* Beds. On the other hand the absence of pelagic mollusks in sample 1 suggests no inflow of open sea water into the depositional site during deposition of the *Dosinia* Bed. It is most likely that this bed was deposited in a strongly protected embayment. The inference on the depositional environment of the Takamatsu Silty Sandstone from pelagic mollusks supports that of Hayasaka (1961) above mentioned.

Systematic paleontology

Superfamily Heteropoda d'Orbigny, 1836
Family Atlantidae Wiegmann and Ruthe, 1832

Genus *Atlanta* Lesueur, 1817

Atlanta peroni Lesueur, 1817
(Figs. 3-5-6)

Atlanta peroni Lesueur, 1817, p. 390, pl. 2, figs. 1, 2; Shibata and Ujihara, 1983, p. 154, pl. 46, fig. 2; Grecchi, 1984, p. 19, pl. 1, fig. 19, pl. 2, figs. 1, 2; Grecchi and Bertolotti, 1988, p. 120, pl. 2, fig. 3.

Atlanta peronii Lesueur. Buccheri, 1978, p. 124, pl. 1, fig. 1.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. The apertural part is missing in all specimens. Shell flattened, with 3 1/2 whorls, separated by impressed suture. Embryonic shell consisting of one whorl, small. Spire slightly elevated, conical, its top faintly projecting beyond the plane of the last whorl in side view. The last whorl large, with a tall keel. The keel not inserted between inner lip and penultimate whorl. Surface of the shell smooth.

Dimensions (in mm) -.

	Height	Diameter
KC20201	0.57	1.5
KC20202	0.66	1.9

Discussion -. *Atlanta peroni* closely resembles *Atlanta gaudichaudi* Souleyet, but spire whorls more rapidly increase in diameter distally, and the embryonic shell is more depressed.

Atlanta lesueuri Souleyet, 1852
(Fig. 3-1)

Atlanta lesueuri Souleyet, 1852, p. 380, pl. 20, figs. 1-8.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. The present species is represented by a single specimen. Whorls 3, separated by distinct suture. Spire small, conical, its top projecting beyond the last whorl in apertural view. The last whorl large, about two times as large as spire in diameter. Aperture wide, with a fissure on outer lip. Keel high, not penetrating between inner lip and penultimate whorl. Surface smooth. Dimensions; height 0.57 mm, diameter 1.5 mm (KC20203).

Discussion -. *Atlanta lesueuri* differs from the preceding species in having a smaller spire. The specimen from the *Tonna* Bed constitutes the first fossil record of this species.

Atlanta turriculata d'Orbigny, 1836
(Figs. 3-2-4)

Atlanta turriculata d'Orbigny, 1836, p. 173, pl. 20, figs. 5-11; Shibata and Ujihara, 1983, p. 157, pl. 47, fig. 4.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Whorls about 4 1/2. Embryonic shell swollen. Spire turreted, spire whorls very slowly increasing in diameter. Suture canaliculate. Spire whorls and the initial 1/4 of the last whorls ornamented with wavy spiral threads; spiral threads seven in number on the initial part of the last whorl. The last whorl bearing a keel. In one specimen the keel is inserted between inner lip and penultimate whorl. The underside of the last whorl slightly inflated, provided with wavy spiral threads. Aperture wide, with a fissure on outer lip. Umbilicus deep.

Dimensions (in mm) -.

	Height	Diameter
KC20204	0.59	1.4
KC20205	-	1.8

Discussion -. The present species resembles *Atlanta fusca* Souleyet, but the spire is more elevated and slenderer.

Order Thecosomata de Blainville, 1824
Suborder Euthecosomata Meisenheimer, 1905
Family Limacinidae Gray, 1847

Genus *Limacina* Bosc, 1817

Limacina inflata (d'Orbigny, 1836)
(Figs. 4-1-2)

Atlanta inflata d'Orbigny, 1836, p. 174, pl. 12, figs. 16-19.
Limacina inflata (d'Orbigny). Yamakawa and Ishikawa, 1912a, p. 2, pl. 1, fig. 1; Collins, 1934, p. 179, pl. 7, figs. 3-8; Almogi-Labin and Reiss, 1977, p. 13, pl. 7, figs. 5, 7, p. 36, pl. 7, figs. 3, 4, 8, 9; Buccheri, 1978, p. 126, pl. 1, fig. 3; Shibata and Ujihara, 1983, p. 158, pl. 43, fig. 1; Grecchi, 1984, p. 14, pl. 1, fig. 5; Grecchi and Bertolotti, 1988, p. 101, pl. 1, fig. 1; Janssen, 1989, p. 14, pl. 2, figs. 5-7, pl. 3, fig. 11, pl. 10, fig. 2; Janssen, 1998, p. 99, pl. 1, fig. 12; Mimoto and Nakao, 2004, p. 20, fig. 2-5.
Spiratella inflata (d'Orbigny). Colantoni and others, 1970, p. 176, pl. 24, fig. 7; D'Alessandro and others, 1979, p. 82, pl. 15, fig. 11.
Limacina (*Heliconoides*) *inflata* (d'Orbigny). Janssen, 1999, p. 14, pl. 2, figs. 10, 11.
(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Shell coiled in one level. Whorls 2 1/2, separated by clear suture. Spire small, not visible in side view. The last whorl much larger than the preceding ones, well swollen. Aperture large, semilunar, basal lip projected. Umbilicus narrow, circular, deep. Surface of the shell smooth.

Dimensions (in mm) -.

	Height	Diameter
KC20207	0.94	1.3
KC20208	0.65+	1.1

Discussion -. The small spire hidden by the last whorl in side view is diagnostic of *Limacina inflata*.

Limacina lesueurii (d'Orbigny, 1836)
(Figs. 4-3-6)

Atlanta lesueurii d'Orbigny, 1836, p. 177, pl. 20, figs. 12-15.
Limacina lesueurii (d'Orbigny). Buccheri, 1978, p. 128, pl. 1, fig. 4.
Limacina lesueuri (d'Orbigny). Shibata and Ujihara, 1983, p. 159, pl. 43, figs. 5, 6.
(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Whorls about 4 1/2, separated by distinct suture. Spire low, conical, visible in side view. Spire whorls rather regularly increase in diameter. Aperture large, its inner border straight. Umbilicus narrow, semilunar. Surface of the shell smooth.

Dimensions (in mm) -.

	Height	Diameter
KC20209	0.51	0.63
KC20210	0.67	0.74
KC20211	0.41	0.50
KC20212	-	0.73

Discussion -. *Limacina lesueurii* differs from *Limacina inflata* in having an elevated spire.

Limacina bulimoides (d'Orbigny, 1836)
(Fig. 4-8)

Atlanta bulimoides d'Orbigny, 1836, p. 179, pl. 12, figs. 36-38.
Spiratella bulimoides (d'Orbigny). Colantoni and others, 1970, p. 178, pl. 24, figs. 3-4.
Limacina bulimoides (d'Orbigny). Almogi-Labin and Reiss, 1977, p. 35, pl. 7, figs. 1, 2; Buccheri, 1978, p. 127, pl. 1, fig. 5; Almogi-Labin, 1982, p. 56, pl. 1, figs. 1-4; Shibata and Ujihara, 1983, p. 158, pl. 43, figs. 3, 4; Grecchi, 1984, p. 15, pl. 1, fig. 2; Grecchi and Bertolotti, 1988, p. 102, pl. 1, fig. 4; Janssen, 1998, p. 99, pl. 1, figs. 6-8.
(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Shell large for the genus *Limacina*, turreted, whorls about 4 1/2 including one embryomental one. Spire convex conical, about 1/3 of the shell height. Suture distinct. Aperture semilunar, its inner border straight. Umbilicus very narrow. Surface of the shell smooth. Dimensions; height 0.82 mm, diameter 0.55 mm (KC20213).

Discussion -. The present species has a higher spire than *Limacina trochiformis*.

Limacina trochiformis (d'Orbigny, 1836)
(Fig. 4-7)

Atlanta trochiformis d'Orbigny, 1836, p. 177, pl. 12, figs. 29-31.

Spiratella trochiformis (d'Orbigny). Colantoni and others, 1970, p. 177, pl. 24, figs. 5, 6.

Limacina trochiformis (d'Orbigny). Almogi-Labin and Reiss, 1977, p. 14, pl. 8, figs. 1, 3, 4, pl. 9, figs. 2, 3, p. 36, pl. 8, figs. 2, 5-7, pl. 9, fig. 1; Buccheri, 1978, p. 126, pl. 1, fig. 6; Almogi-Labin, 1982, p. 56, pl. 1, figs. 5-7; Shibata and Ujihara, 1983, p. 158, pl. 43, fig. 2; Grecchi, 1984, p. 15, pl. 1, fig. 3; Grecchi and Bertolotti, 1988, p. 103, pl. 1, fig. 2.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Whorls 3, separated by deep suture, well inflated. Embryonic shell one, inflated. Spire conical, about 1/6 of the shell height. The last whorl well inflated. Aperture large, ovate, its basal part protruded. Columella thickened, nearly straight. Surface of the shell smooth.

Dimensions (in mm) -.

	Height	Diameter
KC20214	0.91	0.76
KC20215	0.53	0.45

Discussion -. Specimens at hand show considerable variation in shape. *Limacina trochiformis* is distinguished from *Limacina lesueurii* by its elevated spire.

Family Cavoliniidae Fisher, 1883

Genus *Creseis* Rang, 1828

Creseis acicula (Rang, 1828)
(Figs. 4-10-12)

Cleodora (*Creseis*) *acicula* Rang, 1828, p. 318, pl. 17, fig. 6; Collins, 1934, p. 207, pl. 9, figs. 6, 7, pl. 13, figs. 7, 8.

Clio (*Creseis*) *acicula* (Rang). Yamakawa and Ishikawa, 1912a, p. 2, pl. 1, fig. 2.

Styliola acicula (Rang). Ladd, 1934, p. 234, pl. 41, fig. 10.

Creseis acicula Rang. Buccheri, 1978, p. 128, pl. 2, fig. 5; Grecchi, 1982, p. 718, pl. 54, figs. 7, 8; Grecchi, 1984, p. 15, pl. 1, fig. 14.

Creseis acicula (Rang). Colantoni and others, 1970, p. 179, pl. 24, fig. 11; Almogi-Labin and Reiss, 1977, p. 10, pl. 4, fig. 3, p. 26, pl. 4, figs. 1, 2; Grecchi and Bertolotti, 1988, p. 104, pl. 1, fig. 7; Janssen, 1999, p. 15, pl. 3, figs. 1, 2.

Creseis acicula acicula Rang. Shibata and Ujihara, 1983, p. 159, pl. 44, fig. 1.

Creseis acicula forma *acicula* Rang. Shibata, 1984, p. 78, pl. 23, figs. 9, 10.

Creseis acicula forma *acicula* (Rang). Ujihara and others, 1990, p. 312, pl. 1, fig. 1; Ujihara, 1996, p. 774, fig. 3.5.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Shell needle-like, with small aberrations. Embryonic shell slightly bulged, hardly constricted at its base, the top rounded. Transverse section and aperture circular. Surface smooth.

Dimensions (in mm) -.

	Length	Diameter
KC20216	5.4	0.47
KC20217	3.6	0.31
KC20218	3.8	0.34

Discussion -. The shell is slenderer than that of *Creseis virgula*. This species is identified with *acicula* in forma level taxon on the basis of the very weak constriction behind the base of the embryonic shell.

Creseis virgula (Rang, 1828)
(Figs. 4-13-15)

Cleodora (*Creseis*) *virgula* Rang, 1828, p. 316, pl. 17, fig. 2.

Clio (*Creseis*) *virgula* (Rang). Yamakawa and Ishikawa, 1912a, p. 3, pl. 1, fig. 3.

Creseis virgula forma *conica* Eschscholtz. Almogi-Labin and Reiss, 1977, p. 11, pl. 4, figs. 6-8.

Creseis virgula forma *virgula* (Rang). Almogi-Labin and Reiss, 1977, p. 26, pl. 4, figs. 4, 5, 9, 10.

Creseis virgula Rang. Grecchi, 1982, p. 717, pl. 52, figs. 4, 5; Grecchi, 1984, p. 15, pl. 1, fig. 6.

Creseis virgula constricta Chen and Bé. Shibata and Ujihara, 1983, p. 160, pl. 44, fig. 2.

Creseis virgula (Rang). Grecchi and Bertolotti, 1988, p. 105, pl. 1, fig. 8.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Shell conical, bent dorsally. Embryonic shell conical, separated from the rest of the shell by a constriction, the posterior part of it bearing a faint constriction beside this one. The top of the embryonic shell rounded. Aperture circular. Shell surface smooth.

Dimensions (in mm) -.

	Length	Diameter
KC20219	2.0	0.47
KC20220	1.9	0.50
KC20221	1.8	0.47

Discussion -. The embryonic shell is more distinctly constricted at its base than that of *Creseis acicula*.

Genus *Styliola* Gray, 1850

Styliola subula (Quoy and Gaimard, 1827)
(Fig. 4-9)

Cleodora subula Quoy and Gaimard, 1827, p. 233, pl. 8D, figs. 1-3.

Styliola sulcifera Gabb, 1873, p. 200; Jung, 1971, p. 216, pl. 19, figs. 14, 15.

Styliola rangiana Tate, 1887, p. 194, pl. 20, fig. 2.

Styliola subulata (Quoy and Gaimard). Bellini, 1905, p. 44.

Clio (*Styliola*) *subula* (Quoy and Gaimard). Yamakawa and Ishikawa, 1912a, p. 4, pl. 1, fig. 4.

Clio (*Styliola*) *lamberti* Checchia-Rispoli, 1921, p. 10, fig. 3.

Cleodora (*Styliola*) *sulcifera* Gabb. Collins, 1934, p. 202, pl. 9, figs. 9-12.

Styliola lamberti Checchia-Rispoli. Sirna, 1968, p. 420, fig. 6; D'Alessandro and others, 1979, p. 84, pl. 16, figs. 43-45; Krach, 1981, p. 122, pl. 1, fig. 10.

Creseis acicula (Rang). Noda, 1972, p. 481, pl. 57, figs. 1-5 (non *Creseis acicula* (Rang, 1828)).

Styliola subula (Quoy and Gaimard). Colantoni and others, 1970, p. 179, pl. 24, fig. 10; Almogi-Labin and Reiss, 1977, p. 15, pl. 9, figs. 4, 5; Buccheri, 1978, p. 130, pl. 1, fig. 9; Grecchi, 1982, p. 719, pl. 52, fig. 3; Shibata and Ujihara, 1983, p. 161, pl. 44, fig. 6; Shibata, 1984, p. 79, pl. 24, figs. 8, 9; Grecchi and Bertolotti, 1988, p. 106, pl. 1, fig. 9; Janssen, 1989, p. 32, pl. 5, figs. 13-19, pl. 6, figs. 1-9; Ujihara and others, 1990, p. 313, pl. 1, fig. 2; Janssen and Zorn, 1993, p. 194, pl. 6, figs. 2-4, pl. 7, fig. 1; Janssen, 1995, p. 29, pl. 2, figs. 1, 2; Ujihara, 1996, p. 774, figs. 3.6-3.9; Janssen, 1999, p. 18, pl. 3, figs. 7-9; Mimoto and Nakao, 2004, p. 20, fig. 2.6.

Styliola cf. *subula* (Quoy and Gaimard). Robba and Spano, 1978, p. 762, pl. 76, figs. 2, 3.

Styliola subula lamberti (Checchia-Rispoli). D'Alessandro and Robba, 1981, p. 617, pl. 61, figs. 1-5.

?*Styliola subula lamberti* Checchia-Rispoli. Shibata and Ujihara, 1989, p. 24, pl. 1, fig. 8.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. The present species is represented by eleven fragmentary specimens. Shell conical, straight. Embryonic shell small, with two constrictions, a distinct one at the base and a faint one in the posterior part. The top of the embryonic shell is pointed. Aperture circular, with an indent of a longitudinal striation. Surface with a queer longitudinal striation starting from a little above the base of post-embryonic shell. Dimensions; length 3.1 mm, diameter 0.69 mm (KC20222).

Discussion -. The embryonic shell is similar in shape to that of *Clio pyramidata,* but it is less bulged.

Genus *Hyalocylis* Fol, 1875

Hyalocylis striata (Rang, 1828)
(Fig. 4-16)

Cleodora (*Creseis*) *striata* Rang, 1828, p. 315, pl. 17, fig. 3.

Creseis striata Rang. Seguenza, 1867, p. 12, fig. 13.

Hyalocylis striata (Rang). Colantoni and others, 1970, p. 180, pl. 24, fig. 9; Buccheri, 1978, p. 129, pl. 2, fig. 6; Grecchi, 1984, p. 16, pl. 1, fig. 4; Shibata and others, 1986, p. 44, pl. 7, fig. 4; Grecchi and Bertolotti, 1988, p. 107, pl. 1, fig. 10; Ujihara, 1996, p. 776, figs. 3.10, 3.11; Janssen, 1999, p. 16, pl. 3, figs. 3-6.

Hyalocylix striata (Rang). Noda, 1972, p. 478, pl. 57, figs. 7, 8; Almogi-Labin and Reiss, 1977, p. 13, pl. 6, figs. 6-8; Shibata and Ujihara, 1983, p. 161, pl. 44, fig. 7; Shibata, 1984, p. 80, pl. 23, figs. 11, 12.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. More than 50 specimens are available, but

they all are fragmentary ones. Shell thin, conical, slightly curved dorsally. Aperture circular. Surface transversely striated. Dimensions; length 2.4 mm, diameter 1.1 mm (KC20223).

Discussion -. The conical shell with transverse striations is diagnostic of *Hyalocylis striata*.

Genus *Clio* Linnaeus, 1767

Clio pyramidata Linnaeus, 1767
(Figs. 5-1-2)

Clio pyramidata Linnaeus, 1767, p. 1094; Yamakawa and Ishikawa, 1912a, p. 4, pl. 1, fig. 5; Colantoni and others, 1970, p. 180, pl. 24, fig. 13, pl. 25, figs. 2, 3; Grecchi, 1975, p. 229, pl. 1, figs. 6, 7; Robba, 1977, p. 599, pl. 21, figs. 2-4, pl. 25, fig. 8; Grecchi, 1982, p. 719, pl. 52, fig. 1, pl. 53, fig. 4; Grecchi, 1984, p. 16, pl. 1, fig. 8; Grecchi and Bertolotti, 1988, p. 108, pl. 1, fig. 5.

Cleodora lanceolata Peron and Lesueur. Seguenza, 1867, p. 9, fig. 8.

Cleodora bowdenensis Collins, 1934, p. 201, pl. 12, figs. 3-7.

Cleodora okinawana Noda, 1972, p. 477, pl. 57, figs. 6, 12, 13.

Clio pyramidata forma *lanceolata* (Lesueur). Almogi-Labin and Reiss, 1977, p. 10, pl. 3, figs. 1, 2; Shibata, 1984, p. 81, pl. 24, figs. 1-3; Shibata and others, 1986, p. 47, pl. 7, figs. 5, 6; Ujihara and others, 1990, p. 315, pl. 1, figs. 10, 11; Janssen, 1995, p. 83, pl. 7, figs. 3-5; Ujihara, 1996, p. 777, figs. 3.23-3.25; Janssen, 1999, p. 21, pl. 3, figs. 3, 13-17.

Clio pyramidata forma *convexa* (Boas). Almogi-Labin and Reiss, 1977, p. 26, pl. 2, fig. 6, pl. 3, figs. 3-6.

Clio pyramidata Linne. Buccheri, 1978, p. 132, pl. 2, fig. 3.

Clio pyramidata lanceolata (Lesueur). Shibata and Ujihara, 1983, p. 162, pl. 44, figs. 5, 8; Mimoto and Nakao, 2004, p. 22, figs. 3.1, 3.2.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. The present species is represented by four fragmentary specimens. Dorsal side triangular in dorsal view, convex, with three longitudinal ribs. Ventral side concave, with a median longitudinal rib. Besides the longitudinal sculpture both sides bearing transverse striations on the surface. Cross-section crescent. Lateral keels thickened, strongly diverging anteriorly. Embryonic shell bulged, separated from the rest of the shell by a constriction. Dimensions; length 5.7+ mm, width 4.7+ mm (KC20224).

Discussion -. The pyramidal shape of the shell is a diagnostic character of *Clio pyramidata*. Specimens at hand are identified with *lanceolata* in forma level taxon on the basis of the strongly diverging lateral keels.

Genus *Cuvierina* Boas, 1886

Cuvierina columnella (Rang, 1827)
(Fig. 5-3)

Cuvieria columnella Rang, 1827, p. 323, pl. 45, B, figs. 1-8.

Cuvierina columnella (Rang). Yamakawa and Ishikawa, 1912a, p. 8, pl. 1, fig. 8; Collins, 1934, p. 222, pl. 14, figs. 6, 7; Buccheri, 1978, p. 138, pl. 2, fig. 4.

*Cuvierina columnella columnell*a (Rang). Shibata and Ujihara, 1983, p. 162, pl. 44, fig. 9.

Cuvierina columnella forma *columnella* (Rang). Shibata, 1984, p. 83, pl. 24, fig. 10.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. A single specimen without the posterior part is available from sampling horizon 7. Shell bottle-shaped, with the greatest width in the posterior part of shell. Aperture triangular, dorsal apertural lip protruding anteriorly. Post-apertural constriction slight. Dimensions; length 7.5+ mm, width 3.2 mm, thickness 3.1 mm (KC20225).

Discussion -. The specimen has a diagnostic character of forma *columnella* as to the position of the greatest width of the shell.

Genus *Diacria* Gray, 1847

Diacria trispinosa (de Blainville, 1821)
(Fig. 5-4)

Hyalaea trispinosa de Blainville, 1821, p. 82.

Hyalaea (*Diacria*) *trispinosa* (Lesueur). Seguenza, 1867, p. 8, fig. 7.

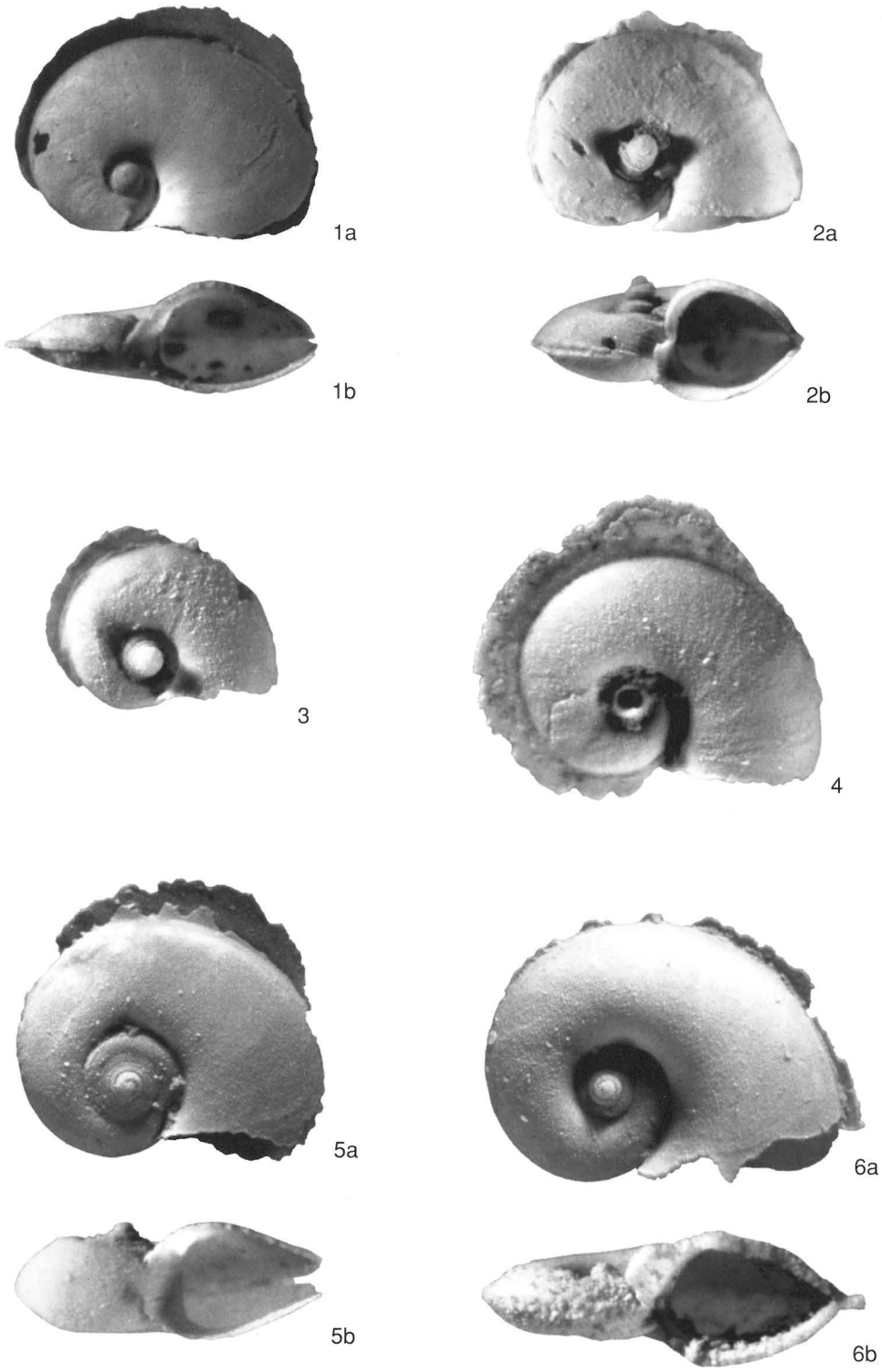

Fig. 3. Pelagic mollusks from the Takamatsu Silty Sandstone at Takamatsu.
1. *Atlanta lesueuri* Souleyet. a, upper, b, apertural view, ×30, KC20203. 2-4. *Atlanta turriculata* d'Orbigny. 2a, upper, 2b, apertural view, ×30, KC20204; 3, upper view, ×30, KC20206; 4, upper view, ×30, KC20205. 5-6. *Atlanta peroni* Lesueur. 5a, upper, 5b, apertural view, ×30, KC20201; 6a, upper, 6b, apertural view, ×30, KC20202.

Fig. 4. Pelagic mollusks from the Takamatsu Silty Sandstone at Takamatsu (continued).
1-2. *Limacina inflata* (d'Orbigny). 1, apertural view, ×40, KC20207; 2a, upper, 2b, apertural view, ×40, KC20208. 3-6. *Limacina lesueurii* (d'Orbigny). 3a, upper, 3b, apertural view, ×40, KC20211; 4a, upper, 4b, apertural view, ×40, KC20210; 5, upper view, ×40, KC20212; 6, apertural view, ×40, KC20209. 7. *Limacina trochiformis* (d'Orbigny). a, upper, b, apertural view, ×40, KC20214. 8. *Limacina bulimoides* (d'Orbigny). apertural view, ×40, KC20213. 9. *Styliola subula* (Quoy and Gaimard). dorsal view, ×20, KC20222. 10-12. *Creseis acicula* (Rang). 10, ×20, KC20216; 11, ×20, KC20217; 12, ×20, KC20218. 13-15. *Creseis virgula* (Rang). 13, ×20, KC20219; 14, ×20, KC20221; 15, ×20, KC20220. 16. *Hyalocylis striata* (Rang). a, dorsal, b, lateral view, ×20, KC20223.

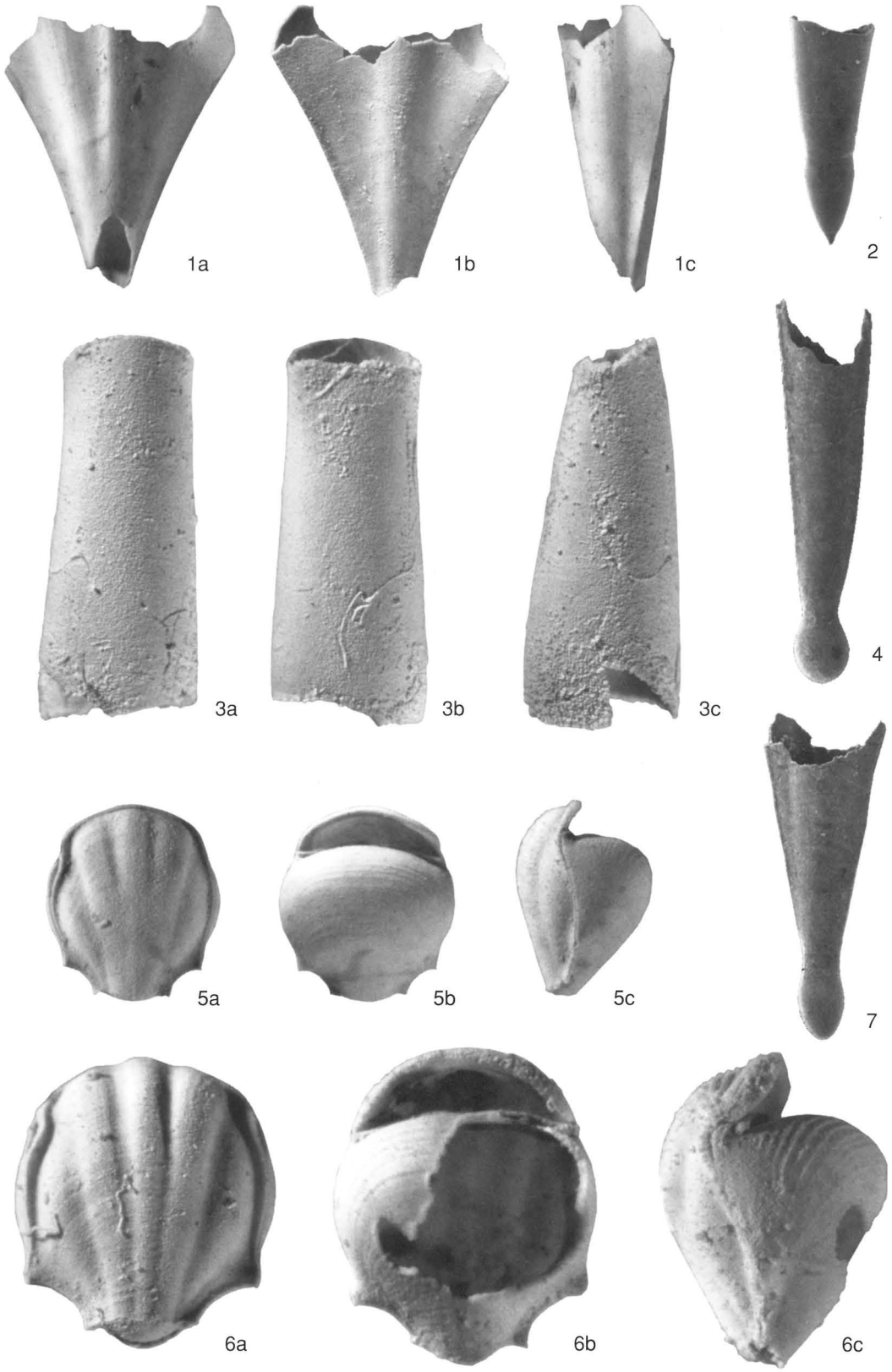

Fig. 5. Pelagic mollusks from the Takamatsu Silty Sandstone at Takamatsu (continued).
1-2. *Clio pyramidata* Linnaeus. 1a, dorsal, 1b, ventral, 1c, lateral view, ×8, KC20224; 2, embryonic part, ×40, KC20235. 3. *Cuvierina columnella* (Rang). a, dorsal, b, ventral, c, lateral view, ×8, KC20225. 4. *Diacria trispinosa* (de Blainville). embryonic part, ×40, KC20226. 5-7. *Diacria quadridentata* (de Blainville). 5a, dorsal, 5b, ventral, 5c, lateral view, ×16, KC20228; 6a, dorsal, 6b, ventral, 6c, lateral view, ×16, KC20227; 7, embryonic part, ×40, KC20229.

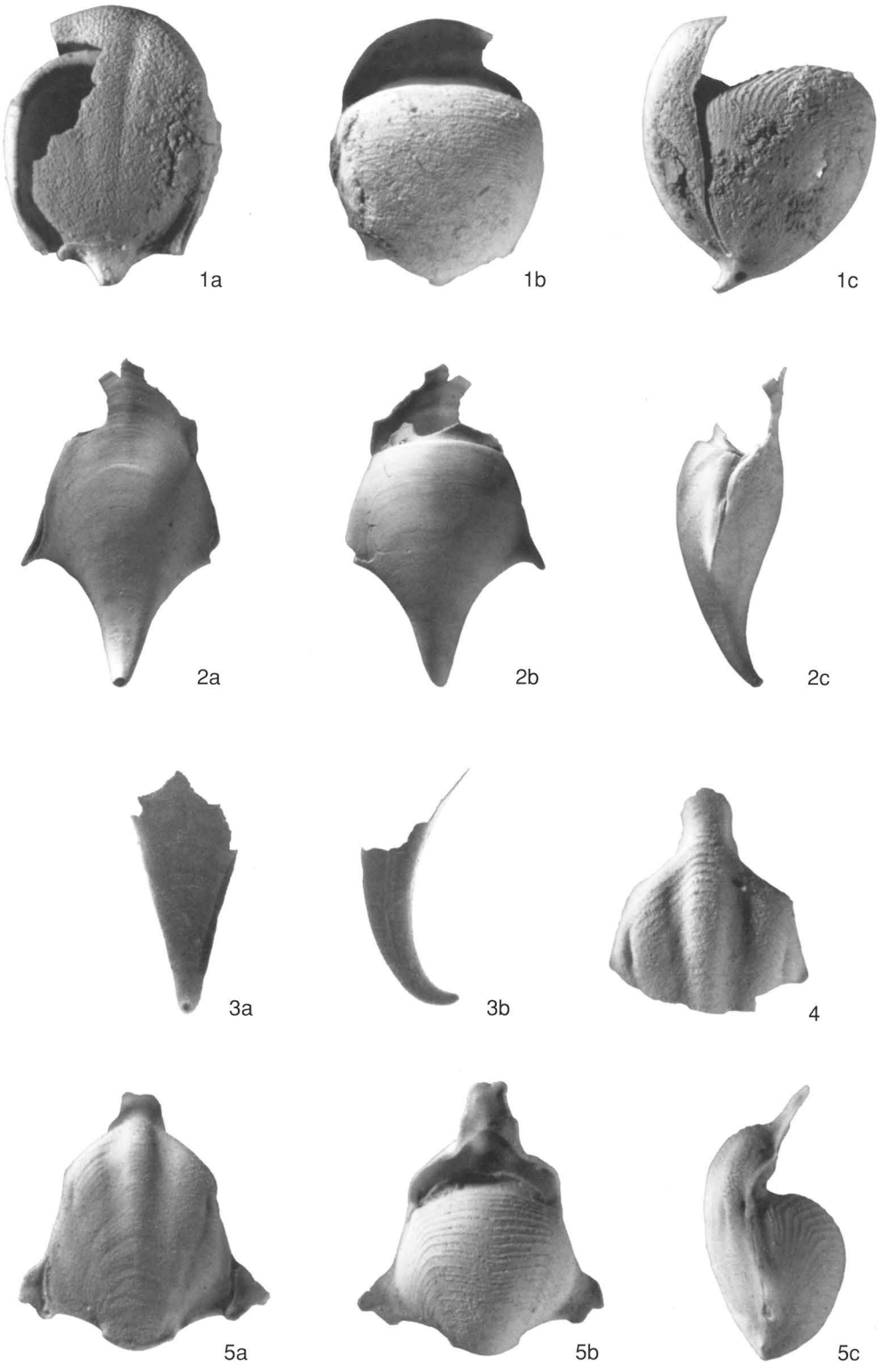

Fig. 6. Pelagic mollusks from the Takamatsu Silty Sandstone at Takamatsu (continued).
1. *Cavolinia globulosa* (Gray). a, dorsal, b, ventral, c, lateral view, ×8, KC20230. 2-3. *Cavolinia inflexa* (Lesueur). 2a, dorsal, 2b, ventral, 2c, lateral view, ×8, KC20231; 3a, dorsal, 3b, lateral view of embryonic part, ×20, KC20232. 4-5. *Diacavolinia longirostris* (de Blainville). 4, dorsal view, ×12, KC20234; 5a, dorsal, 5b, ventral, 5c, lateral view, ×12, KC20233.

Cavolinia (*Diacria*) *trispinosa* (Lesueur). Yamakawa and Ishikawa, 1912b, p. 17, pl. 6, fig. 9.

Diacria trispinosa (Lesueur). Colantoni and others, 1970, p. 182, pl. 24, fig. 12, pl. 25, fig. 4; D'Alessandro and others, 1979, p. 90, pl. 15, fig. 8; Grecchi, 1982, p. 721, pl. 53, fig. 3.

Diacria trispinosa (ms. Lesueur) in de Blainville. Grecchi, 1975, p. 229, pl. 1, figs. 1, 2.

Diacria trispinosa (ms. Lesueur). Almogi-Labin and Reiss, 1977, p. 12, pl. 6, fig. 2.

Diacria trispinosa (ms. Lesueur) (de Blainville). Grecchi and Bertolotti, 1988, p. 111, pl. 1, fig. 13.

Diacria trispinosa forma *trispinosa* (de Blainville). Shibata, 1984, p. 84, pl. 25, figs. 1-3; Shibata and others, 1986, p. 48, pl. 8, figs. 7, 8; Ujihara and others, 1990, p. 318, pl. 2, figs. 1, 2 (non fig. 3).

Diacria trispinosa (de Blainville). Janssen, 1995, p. 107, pl. 9, figs. 3-5; Janssen, 1998, p. 104, pl. 2, fig. 14.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. The present species is represented by two posterior parts. Posterior part mace-shaped, long, dorso-ventrally depressed, with thickened lateral keels. Juvenile shell very slowly increases in width, lenticular in cross-section. Embryonic shell globular, separated from juvenile shell by a distinct constriction, the tip of embryonic shell rounded. Dimensions; length 1.5 mm, width 0.38 mm (posterior part) (KC20226).

Discussion -. The juvenile specimens are identified with *Diacria trispinosa* on the basis of the virgate juvenile shell with the globular embryonic shell.

Diacria quadridentata (de Blainville, 1821)
(Figs. 5-5-7)

Hyalaea quadridentata de Blainville, 1821, p. 81.

Cavolinia (*Diacria*) *quadridentata* (Lesueur). Yamakawa and Ishikawa, 1912b, p. 18, pl. 6, fig. 10.

Diacria quadridentata (ms. Lesueur) (de Blainville) forma *crassa* van der Spoel. Almogi-Labin and Reiss, 1977, p. 32, pl. 5, figs. 5-9, pl. 6, figs. 1, 3-5.

Diacria quadridentata orbignyi (Rang) (Souleyet). Buccheri, 1978, p. 135, pl. 1, fig. 7.

Diacria quadridentata erythra van der Spoel. Shibata and Ujihara, 1983, p. 163, pl. 44, figs. 10, 11.

Diacria quadridentata (ms. Lesueur) (de Blainville). Grecchi and Bertolotti, 1988, p. 112, pl. 1, fig. 12.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Shell ovate in dorsal view, rather thick, with greatest width in the middle of the shell length. Dorsal side convex, protruding antero-ventrally beyond ventral lip. Dorsal lip thickened, ornamented with transverse striations. Dorsal surface with five longitudinal ribs, of them the median one the narrowest. Ventral side vaulted, ventral lip recurved. Anterior part of ventral side sculptured with transverse striations. Posterior projection lost, the rupture formed as a result of its loss ovate, closed by a callus. Lateral spines small, projecting postero-laterally. Juvenile shell triangular, compressed dorso-ventrally, with thickened lateral keels. Embryonic shell globular, with a distinct constriction at its base.

Dimensions (in mm) -.

	Length	Width	Thickness
KC20227	3.1	2.6	2.2
KC20228	1.9	1.7	1.3

Discussion -. The juvenile shell of *Diacria quadridentata* closely resembles that of *Diacria trispinosa,* but the former is larger than the latter in apical angle.

Genus *Cavolinia* Abildgaard, 1791

Cavolinia globulosa (Gray, 1850)
(Fig. 6-1)

Cavolina (*Hyalaea*) *globulosa* Gray, 1850, p. 8.

Cavolinia (s. s.) *globulosa* (Rang). Yamakawa and Ishikawa, 1912b, p. 20, pl. 6, fig. 12.

Cavolinia globulosa (Rang). Shibata and Ujihara, 1983, p. 164, pl. 45, fig. 3; Shibata, 1984, p. 85, pl. 26, figs. 1, 2.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. A single imperfect specimen was found in sample 7. Shell globular, ovate in dorsal view, with

greatest width in the middle of the shell length. The dorsal side inflated, with five obscure longitudinal ribs. Ventral side heavily vaulted, ventral lip recurved. Anterior part of the ventral surface with transverse striations. Posterior projection small, curved dorsally. Lateral spines not well developed. Dimensions; length 5.2 mm, width 4.1 mm, thickness 4.3 mm (KC20230).

Discussion -. This species resembles *Cavolinia mexicana* (Collins) from the Pliocene Agueguexquite Formation in Mexico, but the posterior projection is smaller.

Cavolinia inflexa (Lesueur, 1813)
(Figs. 6-2-3)

Hyalaea inflexa Lesueur, 1813, p. 285, pl. 5, fig. 4.

Cavolinia (s. s.) *inflexa* (Lesueur). Yamakawa and Ishikawa, 1912b, p. 23, pl. 6, fig. 16.

Cavolinia inflexa (Lesueur). Colantoni and others, 1970, p. 183, pl. 26, fig. 3; Buccheri, 1978, p. 137, pl. 2, fig. 2; Grecchi, 1984, p. 18, pl. 1, fig. 13; Grecchi and Bertolotti, 1988, p. 113, pl. 2, figs. 1, 2.

Cavolinia inflexa labiata (d'Orbigny). Shibata and Ujihara, 1983, p. 165, pl. 44, fig. 4, pl. 45, fig. 4.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Shell spoon-shaped, with long posterior projection. Dorsal side slightly inflated, projecting far beyond ventral lip. The main part of dorsal side having no sculpture on the surface. Dorsal lip tapering anteriorly, provided with a longitudinal ridge in the center. Ventral side more inflated than dorsal side, ventral lip recurved. Surface of ventral side smooth. Posterior projection long, curved dorsally, with blunt tip. Lateral spines well developed, projecting postero-laterally, tip pointed. Dimensions; length 6.2 mm, width 3.8+ mm, thickness 2.0 mm (KC20231).

Discussion -. Specimens at hand have characteristics of *labiata* in the taxonomic level of forma.

Genus *Diacavolinia* Spoel, 1987

Diacavolinia longirostris (de Blainville, 1821)
(Figs. 6-4-5)

Hyalaea longirostris de Blainville, 1821, p. 81.

Cavolinia (s. s.) *longirostris* (Lesueur). Yamakawa and Ishikawa, 1912b, p. 19, pl. 6, fig. 11.

Cavolinia longirostris forma *flexipes* van der Spoel. Almogi-Labin and Reiss, 1977, p. 25, pl. 1, figs. 2-4.

Cavolinia longirostris forma *strangulata* (Deshayes). Buccheri, 1978, p. 136, pl. 1, fig. 8, pl. 2, fig. 1.

Cavolinia longirostris longirostris (de Blainville). Shibata and Ujihara, 1983, p. 164, pl. 45, fig. 5.

Cavolinia longirostris angulosa (Gray). Shibata and Ujihara, 1983, p. 165, pl. 45, fig. 6.

(Literature on Recent occurrences are excluded from the synonymy.)

Description -. Shell triangular in dorsal view. Dorsal side inflated, with five longitudinal ribs. Dorsal lip rostrated, gutter-shaped, projecting antero-ventrally. In one specimen a transverse bulge running along the base of dorsal lip. Ventral side evenly vaulted, with transverse lines, which become obscure in the posterior half. Ventral lip recurved, slightly indented in the middle. Lateral spines protruding postero-laterally, consisting of ventral side shell. Posterior projection lost. The rupture formed as a result of its loss is closed by depression of the dorsal and ventral sides. Dimensions; length 3.4 mm, width 3.1 mm, thickness 1.8 mm (KC20233).

Discussion -. The long, gutter-shaped dorsal lip and the straight lateral spines are characteristic of forma *longirostris* among the formae belonging to *Diacavolinia longirostris*.

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（要　旨）

柴田　博・氏原　温・市原　俊：渥美半島の渥美層群高松シルト質砂岩(中期更新世）産浮遊性貝類.

愛知県渥美半島の渥美層群高松シルト質砂岩（中期更新世）より産出した3種の異足類と15種の翼足類を記載する．これらの種はすべて現生種で，暖水に生息する浮遊性種である．浮遊性貝類は*Mya*（オオノガイ）層から*Tonna*（ヤツシロガイ）層間の7層準で採取した全試料で発見された．これは，2層間の地層の堆積中に頻繁にかまたは恒常的に堆積場所へ外洋水の流入があったことを示す．一方，*Dosinia*（カガミガイ）層の試料には浮遊性貝類が発見されなかったことは，同層堆積時に堆積場所に外洋水の流入がなかったことを示唆する．