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Paleoecology and Taxonomy of Middle Eocene Molluscs from the Shiratake Formation on Takeshima Island, Amakusa Islands, Southwest Japan

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Abstract

Four species of Gastropoda and seven species of Bivalvia were identified in the Middle Eocene Shiratake Formation on Takeshima Island, Goshoura Town, Kyûshû, southwest Japan. The molluscan assemblage is characterized by the dominance of *Colpospira* (*Acutospira*) *tashiroi* Kotaka. Stratigraphic and geographic distribution of *C.* (*A.*) *tashiroi* is concurrent with that of larger foraminifers. This suggests that the indigenous *C.* (*A.*) *tashiroi* assemblage is representative for an open sea shallow marine environment. Described species include *Mesalia goshourensis* sp. nov. (Gastropoda : Turritellidae).

Key words : *Mesalia goshourensis* sp. nov., Middle Eocene, paleoecology, Shiratake Formation, taxonomy

Introduction

Marine sediments are dominant among the Paleogene formations, broadly developed in the Amakusa Islands of Kyûshû, southwest Japan (Figure 1). Several mollusc yielding horizons occur. First Yokoyama (1911) described and illustrated three Paleogene bivalves from "Hangôchi" [correctly Hangawachi] in Hondo City, Kumamoto Prefecture. Subsequently, the molluscan faunas have been studied mainly from biostratigraphical and taxonomical points of views (e.g. Nagao, 1928a, b; Inoué, 1962; Mizuno, 1964; Tashiro, 1984; Sakakura *et al.*, 2004). However, since Nagao's (1928a, b) comprehensive work on Paleogene molluscan faunas in the coalfields of northwestern Kyûshû, taxonomical studies have been aiming only at updating restricted groups (e.g. *Acesta* : Oyama, 1943; *Colpospira* (*Acutospira*): Kotaka, 1950, 1959; *Eucrassatella* : Tashiro, 1984; *Venericardia* (*Pacificor*) : Tashiro, 1984 and Sakakura *et al.*, 2004). Paleoecology having lagged behind, the present study aims at both the paleoecology and taxonomy of the molluscan fauna of the Shiratake Formation on Takeshima Island, central part of the Amakusa Islands.

Geological setting, Stratigraphy and Biostratigraphy

The contact of the Paleogene with its basement, the Upper Cretaceous Himenoura Group, is either by stratigraphic unconformity or by fault contact in the Amakusa area. A few synclinal structures occur with NNE–SSW axes (e.g. Nagao, 1926a–e; Matsushita, 1949; Takai *et al.*, 1997; Otsuka *ed.*, 2001). Because of its rather wide distribution and great thickness (Takai *et al.*, 1997), its stratigraphy varies. This has resulted in the adoption of several subdivisions, not only distinguishing between northeast (Uto Peninsula and Amakusa-Kamishima Island) and southwest (Amakusa-Shimoshima Island), but also between the various authors (e.g. Nagao, 1926a–e ; Matsushita, 1949; Hatae, 1959; Miki, 1972; Takai and Satoh, 1982; Yasuda, 1984). In this study, we principally follow Nagao (1926a–c) for the northeast and Matsushita (1949) and Miki (1972) for the southwest (Figure 2).

The Paleogene is subdivided, in ascending order, into the Miroku, Hondo and Sakasegawa Groups (Nagao, 1926a–e). Only the Miroku Group and the lower part of the Hondo Group occur on Takeshima Island and its vicinity (Nagao, 1926a–e; Hatae, 1960; Shimamura and Tsukawaki, 1997; Kawaji, 2000; Otsuka *ed.*, 2001; Figure 3).

In the northwestern part of the Amakusa area, the Miroku

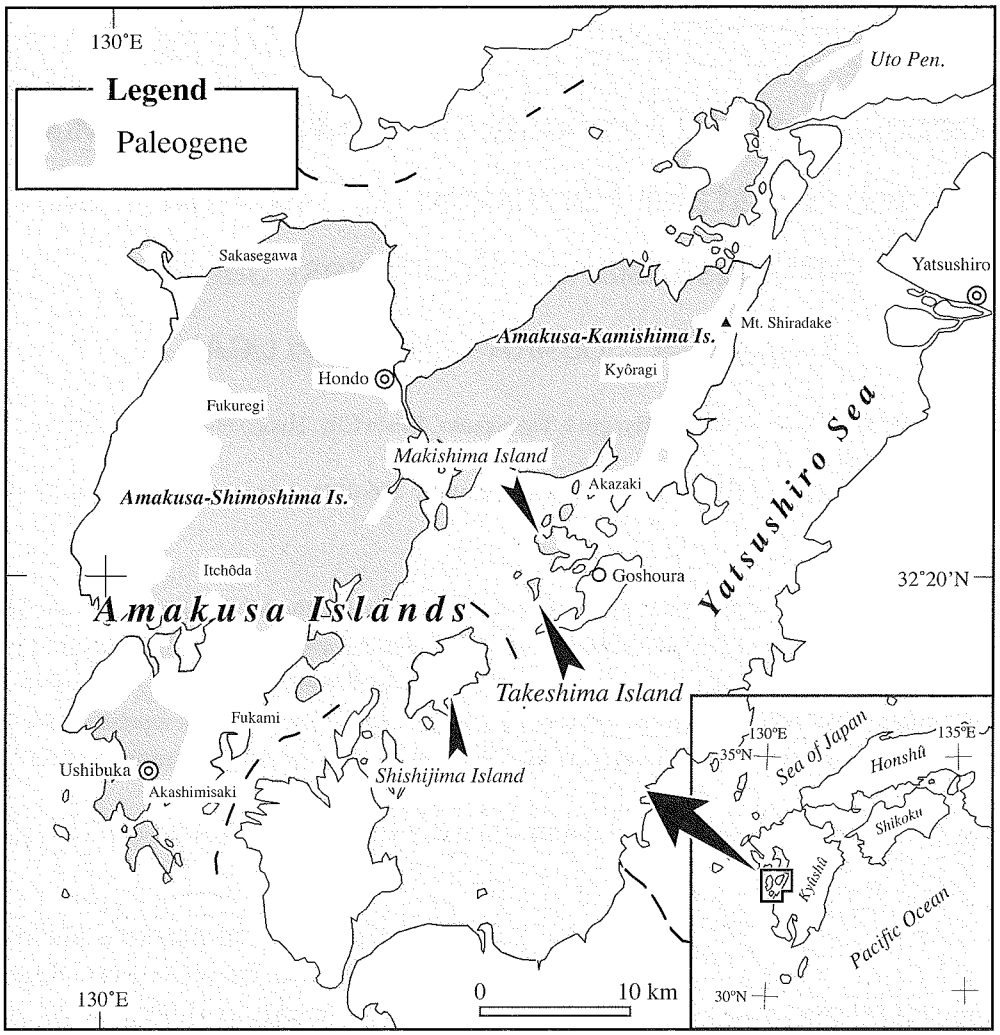

Figure 1. Location of the study area and distribution of Paleogene strata in the Amakusa Islands (simplified from Otsuka *ed.*, 2001).

Group consists at its base of the Akasaki Formation (Nagao, 1926a) that is characterized by some land mammals yielding flood plain deposits (e.g. Miyata and Tomida, 1998 ; Miyata *et al.*, 2005). The thickness is 120–220 m. The overlying Shiratake Formation (Nagao, 1926a; emend. Akagi, 1936; formerly Shiratake Sandstone), is the object of the present study. The Shiratake Formation, which overlies the Akasaki Formation either conformably or disconformably, consists mainly of arkosic medium-grained sandstone. The maximum thickness reaches about 190 m (Inoué, 1962). The Shiratake Formation yields marine molluscs and larger foraminifers (e.g. Nagao, 1923, 1928a; Hatae, 1960; Inoué, 1962; Iwasaki, 1997). In the southwestern area, the marine sediments covers the Cretaceous unconformably, without non-marine deposits like the Akasaki Formation in between (e.g. Nagao, 1926b; Matsushita, 1949; Miki, 1972; Tashiro and Otsuka, 1978 ; Otsuka, 2002). The lower limit varying among authors, different lithostratigraphic term were also coined (e.g. Nagao, 1926a; Matsushita, 1949; Hatae, 1959; Miki, 1972; Tashiro and Otsuka, 1978). Adopted herein is the Fukuregi Formation (Matsushita, 1949; emend. Miki, 1972), and its upper part is correlated with the Shiratake Formation. The stratigraphic equivalence of its lower part with the Akasaki Formation remains controversial (see Tashiro and Otsuka, 1978; Takai and Satoh, 1982).

The Miroku Group, which dealt with in the present study, is conformably overlain by the Hondo Group, consisting of the Kyôragi and Toishi Formations in the northeastern area and of the Shikiyama and Toishi Formations in the southwestern area. The Hondo Group is overlain in both areas by the Itchôda Formation of the Sakasegawa Group.

Mizuno (1964), who established Paleogene and early Neogene molluscan biochronology, referred the Miroku Group and Toishi Formation to the Takashima Stage and the Sakasegawa Group to the Okinoshima Stage, respectively (Figure 2). He considered the Takashima Stage to be of

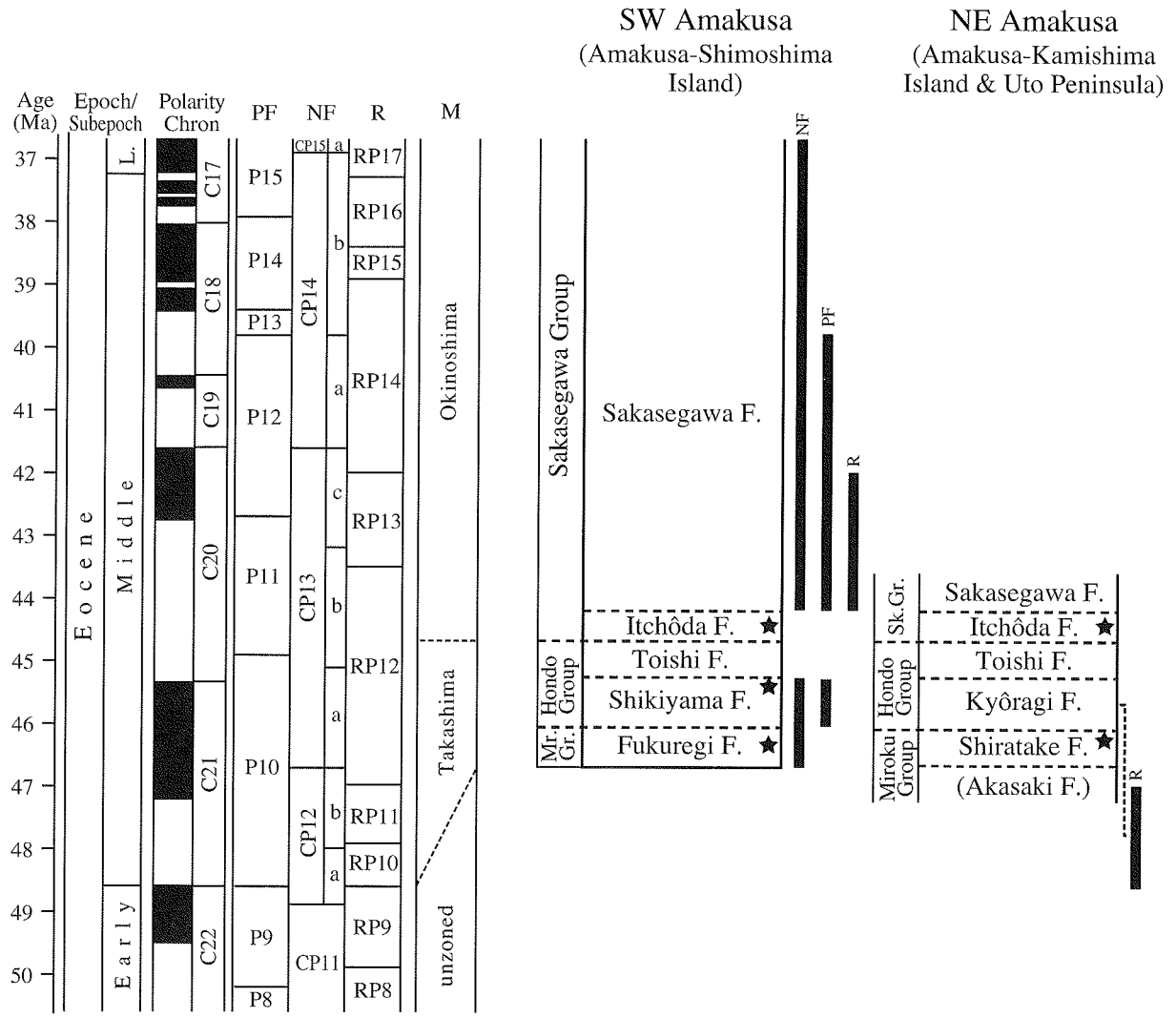

Figure 2. Geochronologic correlation of Paleogene in Amakusa area.
Magnetic polarity: Ogg and Smith (2004); PF (planktonic foraminifera): Berggren (1969); NF (nannofossils): Okada andBukry (1980); R (Radiolaria): Sanfilippo and Nigrini (1998); M (molluscs): Mizuno (1964). Magneto-biostratigraphic correlation after Lutenbacher *et al.* (2004).
Data source: PF: Yasuda (1984); NF: Tashiro *et al.* (1980), Okada (1992); R: Yasuda (1984), Aita *et al.* (1997a, b), Odo *et al.* (2001). Mr.Gr.: Miroku Group; Sk.Gr.: Sakasegawa Group. Black star: molluscan fossiliferous horizon.

the Early Eocene age and the Okinoshima Stage to be of the Middle to early Late Eocene age.

The planktonic microfossil studies from the 1980s onward have enable the Paleogene sediments in the Amakusa area to correlate with the international geologic time scale. Tashiro *et al.* (1980) refers a calcareous nannofossil assemblage from the lower part of the Fukuregi Formation to Zone CP12 of Okada and Bukry (1980). Yasuda (1984) correlated the Shikiyama Formation and Sakasegawa Formation to planktonic foraminiferal zones P10–P11 and P11–P12 of Berggren (1969), respectively as well as to the radiolarian *Tyrsocyrtis triacantha* and *Podocyrtis ampla* Zones of Riedel and Sanfilippo (1978), respectively. Okada (1992), after examination of the material of Tashiro *et al.* (1980) and of two additional samples from lower in the section, reassigned the Fukuregi Formation to calcareous nannofossil Subzone CP13a. He also referred assemblages from the Shikiyama Formation and from the Sakasegawa Group to Subzones CP13a and CP13b–lower part of CP15b, respectively.

Aita *et al.* (1997a, b) referred a radiolarian assemblage from the Kyôragi Formation on Makishima Island, located about 3 km northeast of Takeshima Island, to the upper part of the *Theocotyle cryptocephala* to the *Thyrsocyrtis triacantha* Zones. Ohto *et al.* (2001) referred radiolarian assemblages in the upper part of the Miroku Group and

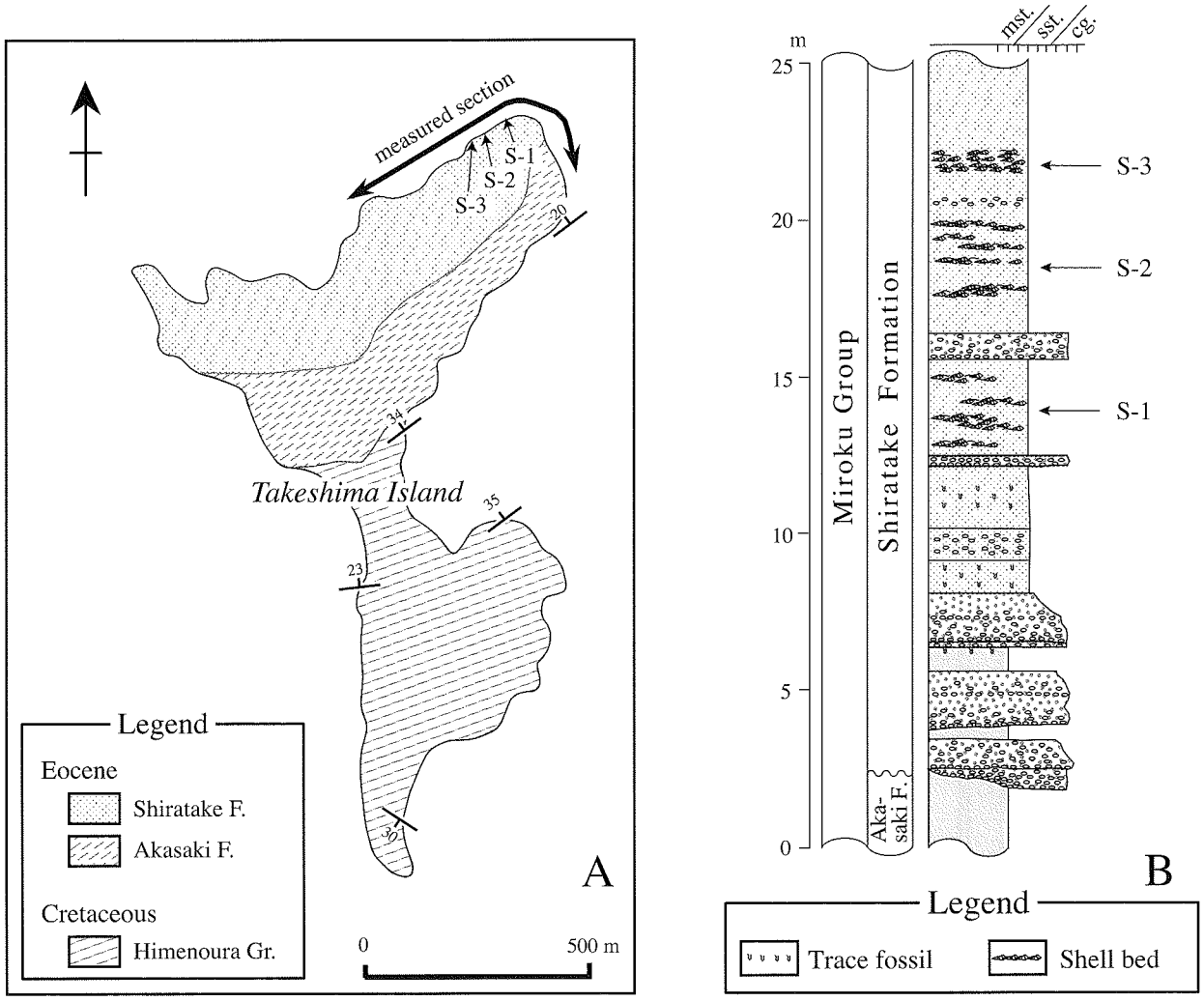

Figure 3. Geologic map of Takeshima Island (A) and columnar section of the Shiratake Formation (B). Fossil locality and sample horizon also indicated. mst.: mudstone; sst.: sandstone; cg. conglomerate.

Kyôragi Formation on Shishijima Island, located at about 7 km southwest of Takeshima Island, to Middle Eocene RP10 to RP 11 of Sanfilippo and Nigrini (1998). Although some geochronologic discrepancies are recognized between calcareous nannofossil and radiolarian scales (Ohto *et al.*, 2001), these results indicate early Middle to Late Eocene ages in the Amakusa area, the Shiratake Formation falling within the early Middle Eocene interval (Figure 2).

Material and method

The molluscan assemblages described herein were collected from three horizons (localities/horizons S-1, S-2 and S-3) along the north coast of Takeshima Island (Figure 3A), in the middle to upper part of the Shiratake Formation (Figure 3B). The preservation of the specimens is poor as shell material is generally absent. The heavily weathered specimens are mostly represented as molds, hence the use of a vinyl polysiloxane inpression material (Provil® Novo, Putty®, regular set, Heraeus Kulzer Inc., Germany) for examination of the shell characters.

Due to their poor preservation, the imprecise abundance of specimens of each species is given according to the following relative scale: R (rare), F (few), C (common), A (abundant).

The Molluscan assemblage

Four species of Gastropoda and seven species of Bivalvia were identified in the Shiratake Formation on Takeshima Island (Table 1). Mizuno (1964) referred the fauna of the Shiratake Formation as one of the representatives of the early Middle Eocene Takashima Stage, containing the gastropods *Colpospira* (*Acutospira*) *tashiroi* Kotaka and *Neverita eocenica* (Nagao) and the bivalve *Callista* (*Microcallista*) *ariakensis* (Nagao) as index species (Table 2).

Table 1. Mollusca from the Shiratake Formation on Takeshima Island.

Species name / Locality	S-1	S-2	S-3
Gastropoda			
Colpospira (*Acutospira*) *tashiroi* Kotaka	A		A
Mesalia goshourensis sp. nov.	C		C
Neverita eocenica (Nagao)	R		
Sycostoma? sp. indet.	R	R	
Bivalvia			
Portlandia sp. indet.	F		
Septifer? sp. indet.	R		
Lucinidae, gen. et sp. indet.	R		
Venericardia (s.l.) sp. indet.		R	
Tellina (*Tellinella*) *tricarinata* Nagao	C		F
Callista (*Microcallista*) *ariakensis* (Nagao)	C		F
Caestocorbula? *subtumida* (Nagao)	R		

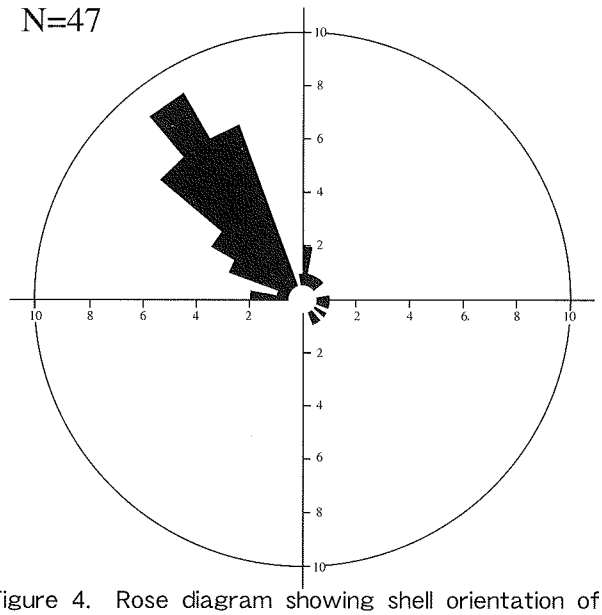

Figure 4. Rose diagram showing shell orientation of *Colpospira* (*Acutospira*) *tashiroi* on a float stone at loc. S-3. Not to direction.

Larger foraminifers *Nummulites* and *Discocyclina* are known to be confined in the early Takashima Stage. The bivalve *Caestocorbula*? *subtumida* (Nagao) once also considered an index of the Takashima Stage (Mizuno, 1964) was also reported from the Iôjima Formation (Okinoshima –Funazu Stages) and Kiuragi and Doshi Formations (Funazu Stage). Noteworthy in the Shiratake Formation is *Tellina* (*Tellinella*) *tricarinata* Nagao, a species that Mizuno (1964) saw as an index species of the Funazu Stage, the range of which extends from early Middle–early Late Eocene.

Locality S-1 : The medium-grained sandstone of the lower horizon is characterized by the dominant gastropod *Colpospira* (*Acutospira*) *tashiroi*. It is associated with the gastropod *Mesalia goshourensis* sp. nov. and small bivalves as *Tellina* (*Tellinella*) *tricarinata*, *Callista* (*Microcallista*) *ariakensis* and *Portlandia* sp. Larger foraminifers are found in the shell beds. While the shells of *C.* (*A.*) *tashiroi* show a preferential orientation on the bedding plane, all bivalves, some fragmented, are disarticulated except for a single specimen of *Caestocorbula*? *subtumida*.

Locality S-2 : Fossils are sporadic and only *Venericardia* (s. l.) sp. and *Sycostoma*? sp. were identified among the collected specimens.

Locality S-3 : The faunal composition of this upper horizon is similar to that of the lower horizon S-1, but the abundant gastropod shells of *C.* (*A.*) *tashiroi* are much larger and harbor a stronger subsutural keel. Several specimens of the gastropod *Mesalia goshourensis* sp. nov., and disarticulated shells of the bivalves *T.* (*Tn.*) *tricarinata* and *C.* (*M.*) *ariakensis* are also associated. Larger foraminifers occur sporadically.

Both the preferential orientation of the highly turreted gastropods (Figure 4) and the common occurrence of isolated and fragmental bivalve shells support the assumption of being influenced by water current (Nagle, 1967).

Comparison with other Molluscan assemblages of Amakusa Islands and Uto Peninsula

There are differences between our Takeshima assem-

Table 2. Range distribution of selected Eocene Mollusca from the Amakusa–Uto Peninsula area. Species with astarisk (*) occured from the Shiratake Formation on Takeshima Island.

Species name	Range	Reference
Colpospira (*Acutospira*) *okadai* (Nagao)	Takashima	Mizuno (1964)
Colpospira (*Acutospira*) *tashiroi* Kotaka*	Takashima	Mizuno (1964)
Neverita eocenica (Nagao)*	Takashima	Mizuno (1964)
Pseudoperissolax yokoyamai Suzuki and Ito	Takashima–Okinoshima	Mizuno (1964)
Sulcobuccinum japonicum (Nagao)	Takashima–Maze	Nagao (1928a, b)
		Mizuno (1964)
Acesta (*Acesta*) *nishiyamai* (Yokoyama)	Okinoshima	Mizuno (1964)
Acesta (*Acesta*) *kumasoana* (Nagao)	Okinoshima	Nagao (1928a)
		Mizuno (1964)
Acesta (*Plicacesta*) *amaxensis* (Yokoyama)	Okinoshima	Mizuno (1964)
Venericardia (*Pacificor*) *ushibukensis* Tashiro*	Takashima	Tashiro (1984)
		Sakakura *et al.* (2004)
Venericardia (*Pacificor*) *nipponica* Nagao	Takashima–Okinoshima	Nagao (1928a, b)
		Mizuno (1964)
"*Venericardia*" *mandaica* (Yokoyama)	Takashima–Okinoshima	Nagao (1928a, b)
		Mizuno (1964)
		Sanbongi *et al.* (1998)
Eucrassatella nipponensis (Yokoyama)	Takashima–Okinoshima	Mizuno (1964)
Eucrassatella hataei (Tashiro)	Takashima	Tashiro (1984)
Tellina (*Tellinella*) *tricarinata* Nagao*	Funazu	Nagao (1928b)
		Mizuno (1964)
Cultellus brevis Nagao	Takashima	Nagao (1928a)
		Inoué (1962)
Callista (*Microcallista*) *ariakensis* (Nagao)*	Takashima	Nagao (1928a)
		Mizuno (1964)
Caestocorbula? *subtumida* (Nagao)*	Takashima–Funazu	Nagao (1928a, b)
		Mizuno (1964)
Lentidium? *kyushuense* (Nagao)	Takashima	Nagao (1928a)
		Mizuno (1964)

blages and those identified by Inoué (1962) within the Shiratake Formation of the Uto Peninsula and its vicinity. This author reports the *Callista* and *Lentidium* assemblages from the lower part of the Shiratake Formation, while he found the *Colpospira* assemblage only in its upper part. No such vertical succession occurs in Takeshima. The *Colpospira* assemblage of Inoué (1962) is characterized by the dominant occurrences of *C.* (*A.*) *okadai* (Nagao), whereas the Takeshima assemblages in both the S-1 and S-3 horizons are represented by *C.* (*A.*) *tashiroi*.

Mizuno (1964) pointed out that the *Colpospira*-dominant molluscan assemblages of the Shiratake Formation and its correlatives can be subdivided into *C.* (*A.*) *okadai* and *C.* (*A.*) *tashiroi* assemblages, on the base of the difference in grain size of the sediments in which they occur. According to this author, *C.* (*A.*) *okadai* has a broader geographic distribution than *C.* (*A.*) *tashiroi*, being found in sediments of more variable grain size and rich in organic matter. In

addition, large-sized specimens of *C.* (*A.*) *okadai* occur in coarse-grained sandstone of the middle part of the Shiratake Formation, whereas *C.* (*A.*) *tashiroi* is found higher up in finer-grained sandstone.

Iwasaki (1997) has indicated that *C.* (*A.*) *okadai* is confined to the southwestern part of the Amakusa area, where it occurs together with large foraminifers *Nummulites* and *Discocyclina*, attesting an open sea, mid to outer ramp environment (e.g. Beavington-Penny and Racey, 2004).

Conclusion

1. Four species of Gastropoda and seven species of Bivalvia were identified in the Shiratake Formation on Takeshima Island.
2. The range of *Tellina* (*Tellinella*) *tricarinata* Nagao is extended to the early Middle Eocene.
3. The molluscan assemblage of the Shiratake Formation on Takeshima Island is dominated by the indigenous gastropod *Colpospira* (*Acutospira*) *tashiroi*. Its stratigraphic and geographic distribution was restricted (Mizuno, 1964; Iwasaki, 1997). *C.* (*A.*) *tashiroi* lived together with larger foraminifers, in an open sea shallow marine environment, in waters agitated by currents, witnessed by its preferential shell orientation.

Systematic paleontology

All type and illustrated specimens are housed at the Goshoura Cretaceous Museum (abbreviated as GCM).

Class Gastropoda
Family Turritellidae
Subfamily Turritellinae
Genus ***Colpospira*** Donald, 1900
Subgenus ***Acutospira*** Kotaka, 1959

Colpospira* (*Acutospira*) *tashiroi Kotaka, 1959

[タシロキリガイダマシ]

Figure 5.7–5.13

Colpospira (*Acutospira*) *tashiroi* Kotaka, 1959, p. 103, pl. 13, figs. 1–10; Shikama, 1964, pl. 27, fig. 23; Kotaka, 1975, pl. Pg-9, fig. 10; Kamada, 1980, pl. Pg-16, figs. 16, 17; Takai and Satoh, 1982, pl. 4, figs. 1–9; Kotaka, 1986, pl. 11, fig. 3; Kotaka, 1996, pl., fig. 6; Otsuka, 2002, pl. 5, figs. 3–5.

Turritella sp. Kawaji, 2000, pl. 4, figs. 1–5.

Material examined.—GCM IVP1745 through IVP1747 (from loc. S-1); GCM IVP1748 through IVP1751 (from loc. S-3).

Discussion.—*Colpospira* (*Acutospira*) *tashiroi* is characterized by its rather large shell (maximum shell height about 60 mm) with the teleoconch consisting of about 10–11, less inflated or weakly concave whorls and a very strong subsutural keel.

Shape of growth lines and spiral pattern being identical, the specimens from S-1 are merely a smaller variation with a narrower apical angle, weaker subsutural keel and additional centrally concave whorls and fine numerous spiral threads.

C. (*A.*) *tashiroi* resembles *Turritella krooni kalosiensis* Beets, 1950 from Celebes [currently Slawesi] Island, Indonesia, found as reworked in alluvial deposits. However, *T. krooni kalosiensis* is distinct from *C.* (*A.*) *tashiroi* by having two keels on the adult whorls.

C. (*A.*) *tashiroi* has a subsutural keel similar to that of *Turritella praecincta* Conrad, 1864, derived presumably from the Upper Paleocene of Alabama, U.S.A. For Kotaka (1996) their relation is homeomorph, as suggested by growth lines and development of spiral cords in these two species show (Kotaka, 1959; Allmon, 1996).

Colpospira (*Acutospira*) *kotakai* (MacNeil, 1964) from the Eocene Miyara Formation on Ishigakijima Island, Okinawa Prefecture, southwest Japan, differs from *C.* (*A.*) *tashiroi* by having a spiral keel on the central part of whorls.

Occurrence.— *C.* (*A.*) *tashiroi* occurs in the Shiratake and Fukuregi Formations, early Middle Eocene.

Subfamily Pareorinae
Genus ***Mesalia*** Gray, 1840

Mesalia goshourensis sp. nov.

[ゴショウラキリガイダマシ，新称]

Figure 5.1a–5.2, 5.4–5.6

Type specimens.—Holotype: GCM IVP1752 (from loc. S-1); paratypes: IVP1753 through IVP1755 (from loc. S-1); IVP1756 through IVP1760 (from loc. S-3).

Type locality.—Locality S-1. Northeastern coast of Takeshima Island, Goshoura Town, Kumamoto Prefecture. About 12 m above from the base of the Shiratake Formation.

Diagnosis.—*Mesalia* with a moderate-sized shell, teleoconch consisting of about nine roundly inflated whorls, and notation of spiral cords . c b a r.

Description.—Shell small (shell height less than 25 mm),

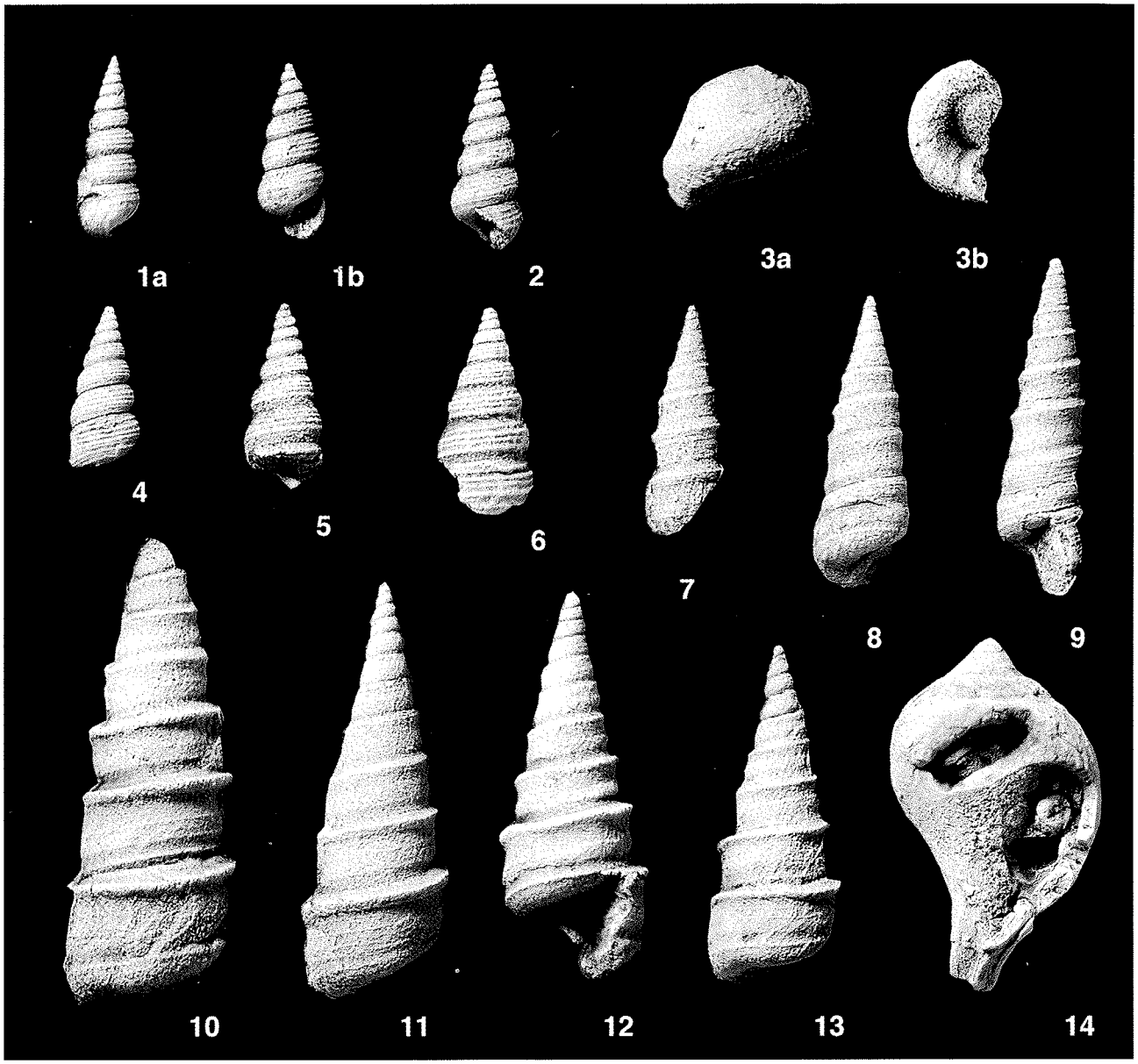

Figure 5. Gastropoda from the Shiratake Formation (All figures×1.5, unless stated otherwise).

1a–b, 2, 4–6. *Mesalia goshourensis* sp. nov. 1a–b. GCM IVP1753 (paratype). 1a. Dorsal view; 1b. apertural view. 2. GCM IVP1752 (holotype), non-apertural view. 4. GCM IVP1754 (paratype), non-apertural view. 5. GCM IVP1756 (paratype), non-apertural view. 6. GCM IVP1757 (paratype), non-apertural view. 3a–b. *Neverita eocenica* (Nagao). GCM IVP 1761. 3a. Dorsal view; 3b. Umbilical view. 7–13. *Colpospira* (*Acutospira*) *tashiroi* Kotaka. 7. GCM IVP1745. 8. GCM IVP1747. 9. GCM IVP1746. 10. GCM IVP1748. 11. GCM IVP1749. 12. GCM IVP1751. 13. GCM IVP1750. All specimens non-apertural views. 14. *Sycostoma*? sp. indet. GCM IVP1762. Non-apertural view, natural size.

All specimens are vinyl casts whitened with magnesium oxide.

turreted; apical angle 27°–35°; teleoconch of about nine roundly inflated whorls; suture fine, distinct; spiral cords five, fine, subequal primarily; spiral cords formula . c b a r following Marwick (1957); c tending to become strengthen whereas a and t becoming obsolete with shell growth; growth lines indistinct, weakly reverse-sigmoidal ; inner lip thin; aperture oblong.

Discussion.—A small-sized shell with rounded whorls, several regular spiral cords and weakly reverse-sigmoidal growth lines assigns the new species to *Mesalia* Gray, 1840.

Mesalia goshourensis sp. nov. closely resembles *M. alabamiensis* (Whitfield, 1865), probably from the Paleocene Wilcox Group of Alabama, U.S.A. (Bowles, 1939). However, *M. alabamiensis* differs from *M. goshourensis* sp. nov. in having lower whorls, sharper spiral cords and a fine spiral

Table 3. Measurements of *Mesalia goshourensis* sp. nov.

GCM reg. no	Height	Diameter	No. of whorls	Apical angle	Spiral notation
IVP1752 (Holotype)	19.0 mm	7.2 mm	8+	30°	c b a r
IVP1753 (Paratype)	18.9 mm	6.3 mm	9	28°	. c b a r
IVP1754 (Paratype)	16.4 mm+	7.1 mm	8	32°	. c b a r
IVP1755 (Paratype)	14.6 mm	6.5 mm	6+	27°	. c b a r
IVP1756 (Paratype)	21.7 mm	9.5 mm	8+	31°	u c . a r
IVP1757 (Paratype)	21.6 mm	~9.8 mm	8+	35°	. c b a r
IVP1758 (Paratype)	15.0 mm+	7.1 mm	6+	31°	c b a .
IVP1759 (Paratype)	19.1 mm+	—	7+	28°	c b a r
IVP1760 (Paratype)	17.7 mm	7.2 mm	7+	28°	. c b a .

cord t.

M. goshourensis has fewer whorls and more irregular spiral cords than Recent *M. brevialis* (Lamarck, 1822), which is the type species of genus *Mesalia*.

M. yessoensis Kotaka, 1959 from the Miocene Piu [Biu] Formation of eastern Hokkaidô, northeast Japan, has a larger shell with broader spiral cords.

Etymology.—After Goshoura Town, Kumamoto Prefecture.

Occurrence.— Shiratake Formation, early Middle Eocene.

Measurements.—Table 3.

Family Naticidae
Subfamily Polinicinae
Genus ***Neveria*** Risso, 1826

Neverita eocenica (Nagao, 1928a)

[シシンツメタガイ，新称]

Figure 5.3a–b

Polynices [sic] (*Neverita*) *eocenica* Nagao, 1928a, p. 118–119, pl. 18, figs. 2–3. [*Polinices*]

Polinices (*Glossaulax*) *eocenica* Nagao. Oyama *et al.*, 1960, p. 50, pl. 5, figs. 8a–d; Kamada, 1980, pl. Pg-16, figs. 9, 10.

Neverita eocenica (Nagao). Hatai and Nisiyama, 1952, p. 235–236; Majima, 1988, Figs. 3.1a–3.3b; Majima, 1989, p. 49–51, pl. 4, figs. 13–15, tab. 17.

Material examined.—GCM IVP1761 (from loc. S-1). One specimen.

Discussion.— The specimen consists only of half of the body whorl, showing a small globose shell with a deeply concave umbilical wall and a large, semicircular, thick umbilical callus with a very feeble transverse groove. Based on these characters, the Takeshima species is referable to *Neverita eocenica* (Nagao, 1928a) from the Middle Eocene Futagojima Formation in the Takashima Coalfield, Nagasaki Prefecture, western Kyûshû.

Occurrence.—Futagojima Formation (Nagao, 1928a, b; Kamada, 1980), Middle Eocene; Shiratake Formation (this study), early Middle Eocene.

Buccinidae
Melongeninae
Genus ***Sycostoma*** Cox, 1931

Sycostoma ? sp. indet.

Figure 5.14

Gastropoda, gen. et sp. indet. Otsuka *et al.*, 2003, pl. 6, figs. 29a–b.

Material examined.—GCM IVP1762 (from loc. S-1), IVP1763 (from loc. S-2).

Discussion.—The present species can be possibly referred to the genus *Sycostoma* Cox, 1931 on the basis of the thick, oval shell with a low spire and a rather long, weakly warped siphonal canal. Thought similar to *Sycostoma bulbiforme* (Lamarck, 1803) from the Eocene of the Paris Basin, France, our material has a larger shell. *Sulcobuccinum japonicum* (Nagao, 1924), an index for the Takashima–Maze Stages (Middle Eocene–earliest Oligocene) of Kyûshû, has a lower, more rounded spire covered by thin callus, mammillate apex and less recurved siphonal canal. Otsuka *et al.* (2003) figured a gastropod (indet.) from the Shiratake Formation

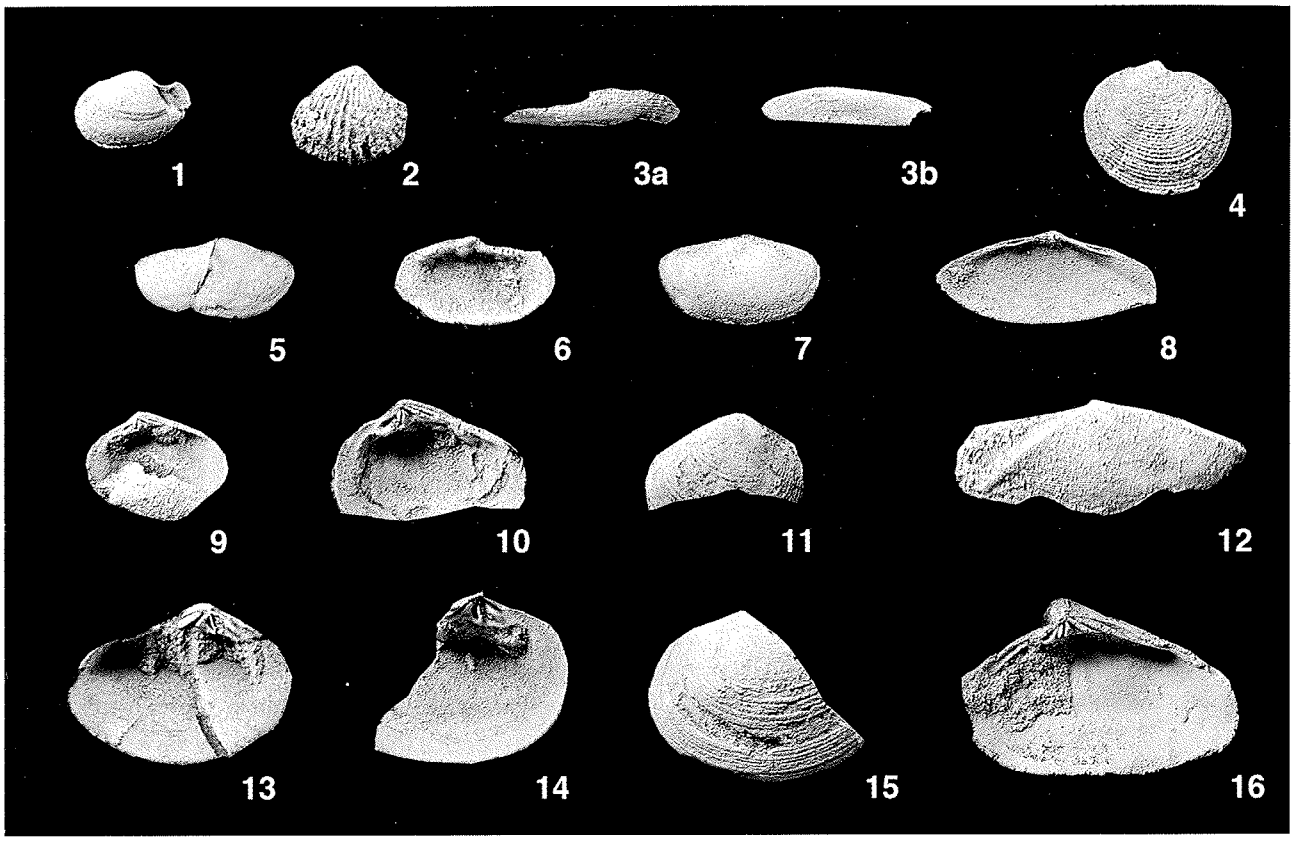

Figure 6. Bivalvia from the Shiratake Formation (All figures×1.5)

1. *Caestocorbula*? *subtumida* (Nagao). GCM IVP1779, left valve. 2. *Venericardia* (s.l.) sp. indet. GCM1769, right valve. 3a–b. *Septifer*? sp. indet. GCM IVP1767. 3a. lateral view. 3b. ventral view. 4. Lucinidae, gen. et sp. indet. GCM IVP1768, right valve. 5–7. *Portlandia* sp. indet. 5. GCM IVP1764, right valve. 6. GCM IVP1765, internal view of right valve. 7. GCM IVP1766, right valve. 8, 12. *Tellina* (*Tellinella*) *tricarinata* Nagao. 8. GCM IVP1770, internal view of right valve. 12. GCM IVP1771, external view of right valve. 9–11, 13–16. *Callista* (*Microcallista*) *ariakensis* (Nagao). 9. GCM IVP1772, internal view of right valve. 10. GCM IVP1773, internal view of right valve. 11. GCM IVP1774, external view of right valve. 13. GCM IVP1775, internal view of left valve. 14. GCM IVP1776, internal view of left valve. 15. GCM IVP1777, external view of right valve. 16. GCM IVP1778, internal view of right valve.
All specimens are vinyl casts whitened with magnesium oxide.

which can be put to the present species.

Class Bivalvia
Family Yoldiidae
Genus ***Portlandia*** Mörch, 1857

Portlandia sp. indet.

Figure 6.5–6.7

Material examined.—GCM IVP1764 through IVP1766 (from loc. S-1).

Description.—Shell small, transversely elongate ovate (height / length ratio about 0.54), weakly inflated; beak situated at slightly anterior of mid length; anterior dorsal margin weakly curved downwardly; posterior ventral margin weakly curved upwardly; posterior end rounded; ventral margin weakly curved; posterior dorso-ventral margin weakly rostrated; shell surface nearly smooth; hinge plate narrow, with fine taxodont teeth; resilifer small, blunt trigonal; adductor muscle scars and pallial line indistinct.

Discussion.—*Several* internal and external molds have been collected. *Portlandia* sp. reported by Mizuno (1964, p. 10, 52) from the Shiratake Formation may belong to the present species. Possibly new, its poor preservation renders its description impossible until more and better preserved specimens are obtained.

Family Mytilidae
Subfamily Mytilinae

Genus ***Septifer*** Récluz, 1848

Septifer ? sp. indet.

Figure 6.3a–b

Material examined.—GCM IVP1767 (from loc. S-1).

Discussion.— The single fragmental external mold with a ventral part of the shell is, on the basis of its concave ventral margin and shell sculpture, consisting of fine radial ribs, with no doubt referable to Mytilidae and possibly to genus *Septifer* Récluz, 1848.

Inoué (1962) first mentioned an incomplete *Septifer* sp. from the Shiratake Formation, which thought not precisely, is possibly comparable with our material.

Family Lucinidae

Lucinidae, gen. et sp. indet.

Figure 6.4

Material examined.—GCM IVP1768 (from loc. S-1).

Discussion.— Certainly belonging to Lucinidae, our specimen has a small compressed circular shell, a low umbone, an obsolete posterior flexure and fine, dense, regularly spaced concentric ribs. A precise generic attribution remains impossible because no internal characters are available.

Family Carditidae
Subfamily Venericardiinae
Genus ***Venericardia*** Lamarck, 1801

Venericardia (s.l.) sp. indet.

Figure 6.2

Material examined.—GCM IVP1769 (from loc. S-2).

Discussion.—The specimen from Takeshima Island has a small roundly subtrigonal shell with about 20 narrow, highly elevated radial ribs. The general shell features resemble *Venericardia mandaica* (Yokoyama, 1911) ranging from the Takashima to Okinoshima Stages of Kyûshû. However, precise comparison can not be made due to the poor preservation.

Our specimen has much smaller shell with fewer radial ribs than *Venericardia* (*Pacificor*) *ushibukensis* Tashiro, 1984, which was originally described from the Fukuregi Formation in the southwestern part of the Amakusa area and was subsequently reported from the Shiratake Formation on Takeshima Island by Kawaji (2000). The precise characters of the taxon are given in Sakakura *et al.*, (2004).

Family Tellinidae
Subfamily Tellininae
Genus ***Tellina*** Linnaeus, 1758
Subgenus ***Tellinella*** Mörch, 1853

Tellina (***Tellinella***) ***tricarinata*** Nagao, 1928b

[サンリョウザクラ, 新称]

Figure 6.8, 6.12

Tellina tricarinata Nagao, 1928b, p. 78–79, pl. 3, figs. 17, 18; Hatai and Nisiyama, 1952, p. 142.

"*Tellina*" *tricarinata* Nagao. Oyama *et al.*, 1960, p. 201, pl. 61, figs. 7a–b.

Material examined.—GCM IVP1770 (from loc. S-3); IVP1771 (from loc. S-1).

Description.—Shell small (shell length less than 25mm), transversely elongate (height / length ratio ab. 0.43) ovate, very weakly inflated; beaks pointed, weakly prosocline, slightly posterior for mid-length; shell surface sculpture consisting of very fine, regular commarginal ribs; anterior dorsal rib fine, crenulated across commarginal ribs; posterior umbonal keel very strong; hinge plate very narrow; cardinal teeth very small; anterior tooth and posterior tooth fine, long; adductor muscle scar linguiform; inner ventral margin smooth.

Discussion.— The present species is assigned to the subgenus *Tellinella* Mörch, 1853, on the basis of its regular fine commarginal ribs, distinct umbonal keel and presence of anterior and posterior lateral teeth, although a radial rib along the anterior dorsal margin is not present in the Recent species. *Tellina* (*Tellinella*) *tricarinata* Nagao, 1928b is similar to *T. equideclivis* Nagao, 1928b from the Eocene Okinoshima Formation in the Takashima Coalfield, northwestern Kyûshû, in having a small shell with fine regular commarginal ribs. However, it differs from the latter species in having a longer shell with a stronger posterior umbonal keel and more anteriorly situated beaks. *T.* (*Tn.*) *crucigera* Lamarck, 1818, living in the Amami Islands and southwards in the West Pacific, is another related species, but is distinguished by having a larger shell lacking an anterior dorsal rib. *T.* (*Tn.*) *rostralis* Lamarck, 1806, from the Eocene in the Paris Basin, France, differs from *T.* (*Tn.*) *tricarinata* by the absence of an anterior dorsal

keel and weaker commarginal ribs.

Occurrence.—Kiuragi Formation (Nagao, 1928b), Late Eocene; Shiratake Formation (this study), early Middle Eocene.

Family Veneridae
Subfamily Pitarinae
Genus ***Callista*** Poli, 1791
Subgenus ***Microcallista*** Stewart, 1930

Callista* (*Microcallista*) *ariakensis (Nagao, 1928a)

[アリアケワスレ，新称]

Figure 6.9–6.11, 6.13–6.16

Macrocallista ariakensis Nagao, 1928a, p. 112, pl. 20, figs. 26–29.
Callista ariakensis (Nagao). Hatai and Nisiyama, 1952, p. 84; Mizuno, 1956, pl. 1, figs. 6a–b; Oyama *et al*., 1960, p. 186–187, pl. 57, figs. 4a–c; Inoué, 1962, pl. 6, figs. 1a–2.
Pitar hinokumai Mizuno (MS). Inoué, 1962, pl. 5, fig. 9. [*nomen nudum*]
Pitar sp. Inoué, 1962, pl. 5, figs. 10a–c.

Material examined.—GCM IVP1772 through IVP1778 (from loc. S-1).

Emended diagnosis.—*Callista* (*Microcallista*) with small trigonally ovate shell, shell sculpture consisting of rather irregular, flat commarginal ribs, and short, oblique anterior lateral teeth.

Description.—Shell small (less than 25mm in shell length), trigonal, ovate, weakly inflated ; beak prosogyrous, situated about one-third from the anterior shell margin ; anterior dorso-ventral margin arched; posterior margin slightly angulated; shell surface sculptured by rather irregular flat concentric ribs.

Hinge of right valve with three cardinal teeth (*3a, 1, 3b*) and two anterior lateral teeth (*AI, AIII*). Left valve hinge with three cardinal teeth (*2a, 2b, 4*) and anterior lateral tooth (*AII*) ; anterior tooth in the left valve (*2a*) not bifurcated.

Anterior adductor muscle scar small, half-moon shaped; posterior adductor muscle scar oblong, weakly impressed; pallial sinus indistinct; nymph very weak; inner ventral margin smooth.

Discussion.—Lacking some cardinal properties, Nagao (1928b) only tentatively assigned his material to *Macrocallista* Meek, 1876. In our material, the anterior tooth (*2a*) in the left valve being not bifurcated (see Figure 5.13, 5.14), it became obvious that the species must be put to subgenus *Microcallista* Stewart, 1930 of genus *Callista* Poli, 1791.

Callista (*Microcallista*) *ariakensis* closely resembles *C.* (*M.*?) *elegans* (Lamarck, 1806) from the Eocene in the Paris Basin, France, in general shell shape and sculpture, but *C.* (*M.*?) *elegans* is smaller. *Paphia munroei* Yokoyama, 1932, from the Paleogene in the Uryû coalfield, Hokkaidô, northeast Japan, is another related species. As a result of his reexamination of the cardinal properties, Miyajima (1959) reassigned this species to *Microcallista*. *C.* (*M.*) *ariakensis* has, however, a higher shell with stronger commarginal ribs. *Callista*? *mitsuiana* Yokoyama, 1911 from the Eocene Manda Group in the Miike Coalfield, western Kyûshû, is also similar to *C.* (*M.*) *ariakensis*, but *C.*? *mitsuiana* has a more rounded shell with finer commarginal ribs.

Occurrence.— Shiratake Formation (Nagao, 1928a; this study), early Middle Eocene; Ginsui Formation (Nagao, 1928a), early Middle Eocene.

Family Corbulidae
Subfamily Caestocorbulinae
Genus ***Caestocorbula*** Vincent, 1910

Caestocorbula*? *subtumida (Nagao, 1928a), comb. nov.

[コウヤギクチベニ，新称]

Figure 6.1

Corbula (s.s.) *subtumida* Nagao, 1928a, p. 115, pl. 22, figs. 6, 7.
Corbula (*Corbula*) *subtumida* Nagao, 1928b, p. 87, pl. 9, figs. 14–15a.
Aloidis subtumida (Nagao). Hatai and Nisiyama, 1952, p. 49.
Caryocorbula (*Anisocorbula*) *subtumida* (Nagao). Oyama *et al*., 1960, p. 208, pl. 58, figs. 4a–d.
Caryocorbula subtumida (Nagao). Inoué, 1962, pl. 6, figs. 3a–c.

Material examined.—GCM IVP1779 (from loc. S-1).

Discussion.—Our specimen is characterized by its small, subelliptical, inflated shell with nearly smooth shell surface, distinctly defined nepionic shell, posteriorly rostrated right valve with a distinct posterior keel and left valve with short posterior margin. Oyama *et al*. (1960) regarded this species as a member of *Anisocorbula* Iredale, 1931 and Inoué (1962) referred it to *Caryocorbula* Gardner, 1926. However, general shape and the rostral "snout" in the posterior part of the right valve are identical to *Caestocorbula* Vincent, 1910. Since cardinal properties are still unknown, we tentatively put our specimen to this genus.

Occurrence.—Futagojima Formation (Nagao, 1928a),

Middle Eocene; ? Doshi Formation (Nagao, 1928b), Late Eocene; Shiratake Formation (Nagao, 1928a; Inoué, 1962; this study), early Middle Eocene.

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天草諸島竹島に分布する中部始新統白嶽層産貝類の古生態・分類学的研究

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要　旨

天草諸島中東部に位置する熊本県御所浦町竹島の中部始新統白嶽層から4種の腹足綱と7種の二枚貝綱が得られた．船津階（後期始新世）の特徴種である *Tellina* (*Tellinella*) *tricarinata* Nagao の本層からの産出は，本種の生存期間が高島階にまで遡ることを示している．本層の貝類化石群集は *Colpospira* (*Acutospira*) *tashiroi* の多産により特徴づけられる．*C.* (*A.*) *tashiroi* の地理的・層位的分布，および大形有孔虫の共産は，本群集が同地性であり，公海の浅海環境を指示することを示す．産出した貝類全種について分類的な考察を行った．*Mesalia goshourensis* sp. nov. [和名：ゴショウラキリガイダマシ，新称] がここに記載される．