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Middle and Late Miocene Marine Bivalvia from the Northern Kanto Region, Central Japan

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Cover Photograph: *Chlamys* (*Nomurachlamys*) *kaneharai* (Yokoyama)

Contents

Abstract

This paper presents a systematic study of fossil marine bivalves from Middle to Upper Miocene deposits in the northern Kanto region, central Japan, as the basis of a better understanding of Neogene molluscan faunal changes in the Japanese Islands. A total of 122 species and subspecies of marine bivalves belonging to 78 genera are discriminated from the Middle to Upper Miocene sequences in the Annaka-Tomioka area, Gunma Prefecture (Tomioka and Annaka Groups), the Karasuyama area, Tochigi Prefecture (Arakawa Group), the Iwadono area, Saitama Prefecture (Tokigawa Group) and some other areas. A new subgenus, *Chlamys* (*Nomurachlamys*), and three new species, *Saccella annakensis*, *Limopsis nodai* and *L. nakajimai*, are described. Six new combinations are proposed: *Ennucula kokozuraensis* (Hatai and Nisiyama, 1949), *Parvamusium tochigiense* (Kanno, 1961), *Semipallium crassivenium* (Yokoyama, 1929), *Securella yokoyamai* (Makiyama, 1927), *Phacosoma hataii* (Masuda, 1963) and *Parilimya kawadai* (Omori, 1952).

Key words: Miocene, Mollusca, Bivalvia, Kanto, Tomioka Group, Annaka Group, Arakawa Group, Tokigawa Group, taxonomy.

関東地方北部の中～後期中新世海生二枚貝類

栗 原 行 人

日本列島における新第三紀貝類相の変遷過程を理解するための基礎的資料として，関東地方北部の中～上部中新統から採集された海生二枚貝類化石の分類学的研究を行った．群馬県安中－富岡地域（安中層群・富岡層群），埼玉県岩殿地域（都幾川層群），栃木県烏山地域（荒川層群）などに分布する中～上部中新統から採集された二枚貝類 78 属 122 種・亜種が識別された．1 新亜属 *Chlamys* (*Nomurachlamys*)，3 新種 *Saccella annakensis*, *Limopsis nodai*, *L. nakajimai* を記載した．また，以下の新組み合わせを提唱した：*Ennucula kokozuraensis* (Hatai and Nisiyama, 1949), *Semipallium crassivenium* (Yokoyama, 1929), *Securella yokoyamai* (Makiyama, 1927), *Phacosoma hataii* (Masuda, 1963), *Parilimya kawadai* (Omori, 1952).

Introduction

In the northern Kanto region, fossiliferous Middle to Upper Miocene marine sequences are developed along the margins of several mountains that consist of pre-Tertiary sedimentary complex. Our knowledge on the chronology and correlation of some of these sequences (*e.g.*, Annaka-Tomioka, Karasuyama, Iwadono areas) has been progressively accumulated by microfossil biostratigraphic studies and radiometric datings during the last two decades. Therefore, these are considered to be the most suitable sequences for the documentation of Middle to Late Miocene faunal succession of marine molluscs in Japan. Occurrences of molluscan fossils have been reported by many authors from both shallow- and deep-water facies of these sequences. However, these are mostly represented by faunal lists in the geologic and stratigraphic studies, and descriptive works are very limited (*e.g.*, Oinomikado, 1938 in the Annaka-Tomioka area; Hirayama, 1954, 1967 and Furusawa *et al*., 1987 in the Karasuyama area; Hatai and Masuda, 1962 in the Iwadono area).

In this study, I describe and illustrate fossil bivalves collected from representative Middle to Upper Miocene sequences in the northern Kanto region. Gastropods, scaphopods and cephalopods will be described separately.

Geologic setting and collecting localities

Miocene marine strata in the northern Kanto region are generally distributed along the margins of the Kanto, Ashio, Yamizo and Abukuma Mountains (Fig. 1). I investigated the following three areas where fossiliferous Middle to Upper Miocene strata are typically developed; the Annaka-Tomioka area in Gunma Prefecture, the Karasuyama area in Tochigi Prefecture, and the Iwadono area in Saitama Prefecture. Moreover, additional samples were obtained from the following three areas; the Utsunomiya area in Tochigi Prefecture, the Joban area in Ibaraki Prefecture, and the Kawamoto area in Saitama Prefecture. Table 1 shows the latest correlation of the Miocene sequence in these areas.

Annaka-Tomioka area

The Annaka-Tomioka area, Gunma Prefecture, is located at the northern margin of the Kanto Mountains, where the Miocene Tomioka and Annaka Groups are developed (Fig. 2A). I investigated the molluscan fossil occurrence mainly in the Isobe district, the central part of the Annaka-Tomioka area, where the upper part of the Tomioka Group and the whole Annaka Group are well exposed along the Usui-gawa River (Fig. 2B). Recently, Takahashi and Hayashi (2004) revised the litho- and chronostratigraphy of the Tomioka and Annaka Groups and divided into seven units in ascending order: Ushibuse, Obata, Idozawa, Haratajino, Niwaya, Haraichi, and Itahana Formations. The former four units belong to the Tomioka Group, and the latter three units belong to the Annaka Group. According to them, the stratigraphic contacts between each formation are conformable except for the base of the Niwaya Formation, which rests on the underlying formations with partial unconformity (Niwaya Unconformity). Many authors have contributed the geochronology of the Tomioka and Annaka Groups on the basis of microfossil biostratigraphy and radiometric datings. Recently, all the available data were summarized by Takahashi and Hayashi (2004). The following brief description is based on Oishi and Takahashi (1990) and Takahashi and Hayashi (2004).

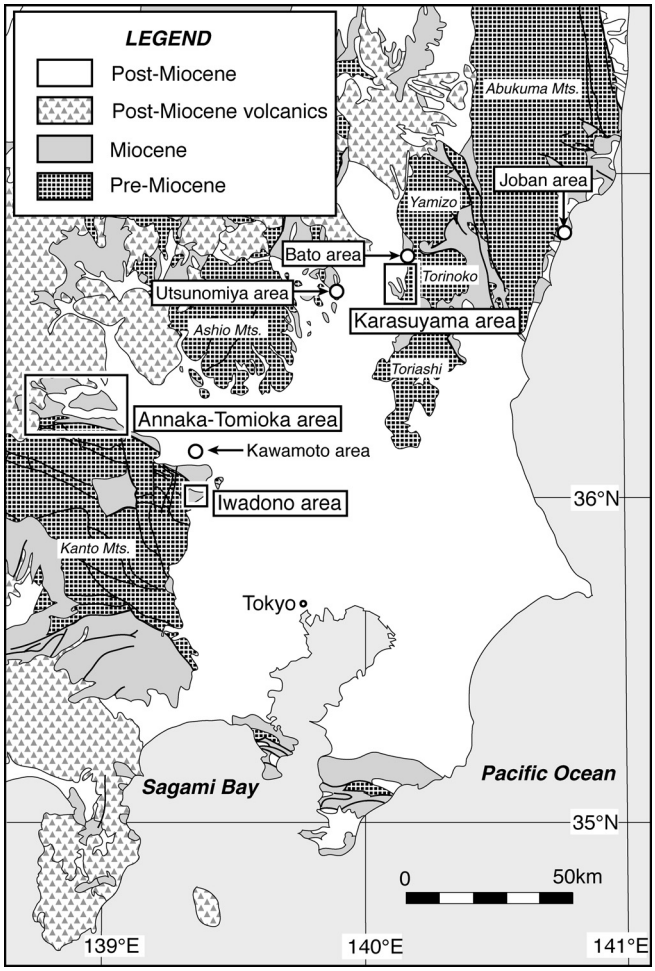
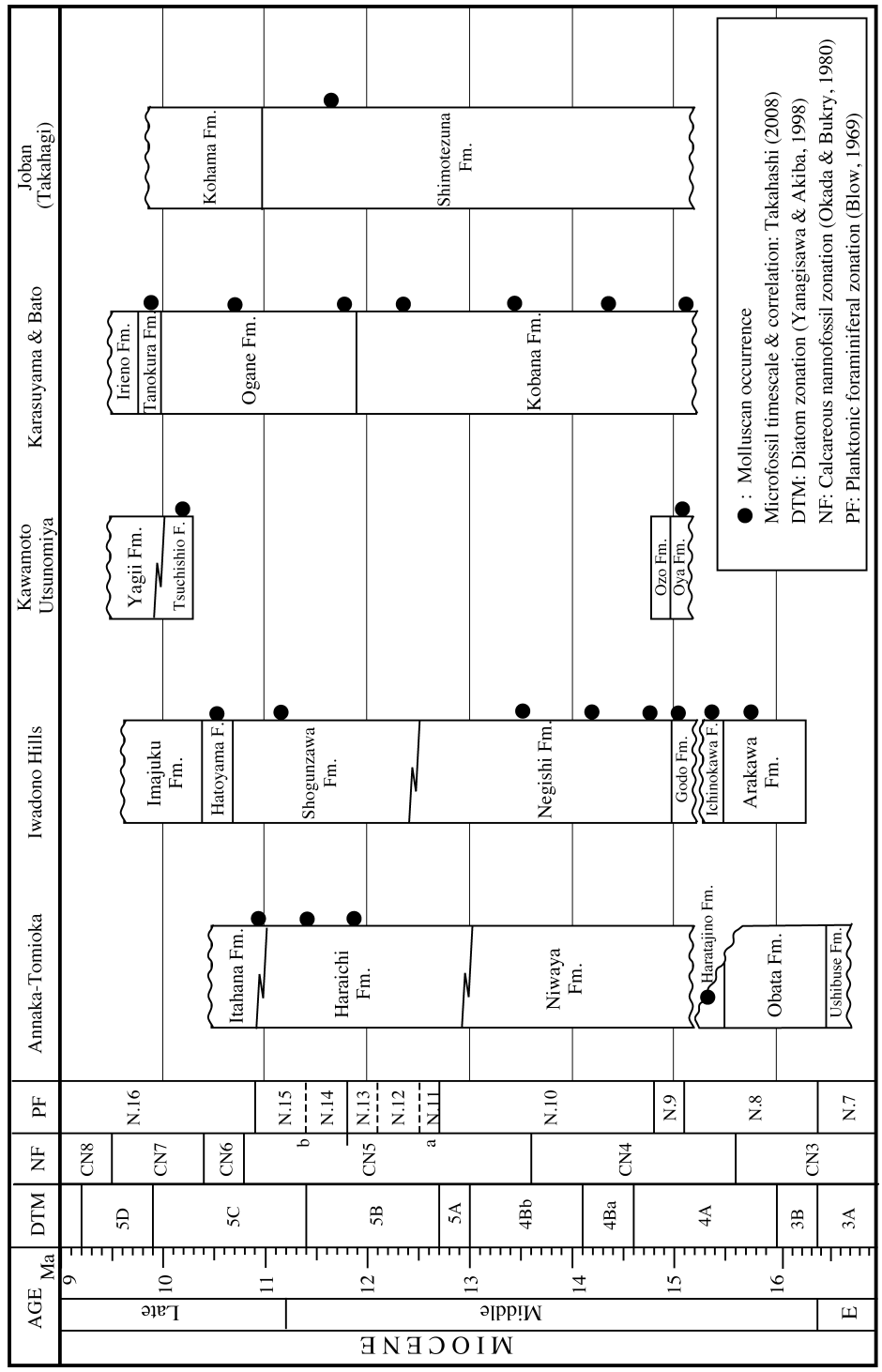


Fig. 1. Geologic sketch map of the northern Kanto region and the study areas.

1) Haratajino Formation, conformably overlying Idozawa Formation, about 40 m thick, consisting of weakly bedded sandy siltstone; bioturbation and tube-shaped concretions common; early Middle Miocene age based on planktonic foraminifers (Blow's N.8); deep-water molluscs common, described by Kurihara (2000).
2) Niwaya Formation, unconformably overlying the Haratajino Formation, about 200 m thick in Isobe district, divided into lower and upper units; lower unit consisting of siltstone or alternation of silty sandstone and sandy siltstone; upper unit consisting of tuffaceous sandstone; early Middle Miocene based on planktonic foraminifers (Blow's N.8–N.9); molluscs very rare.
3) Haraichi Formation, about 550 m thick, consisting of massive siltstone with intercalation of felsic tuff beds; middle to late Middle Miocene age, based on planktonic foraminifers (Blow's N.9–N.14) and radiometric datings; molluscs generally rare but locally abundant.
4) Itahana Formation, about 1200 m thick, divided into lower and upper units; lower unit consisting of alternation of conglomerate-bearing sandstone and sandy siltstone; upper unit con-

Table 1. Latest correlation of Middle to Upper Miocene sequences in the northern Kanto region (modified after Takahashi, 2008).



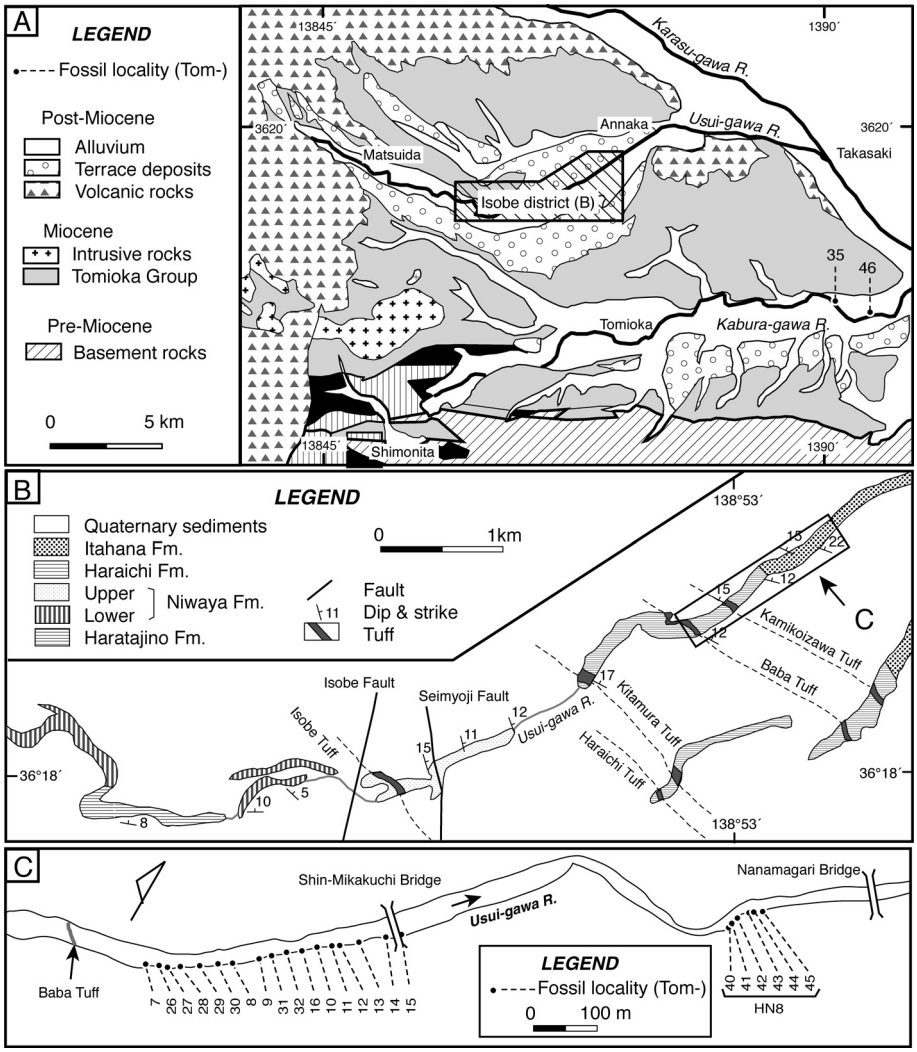


Fig. 2. Map showing fossil mollusc localities in the Annaka–Tomioka area. **A**. Simplified geologic map of the Annaka–Tomioka area. **B**. Geologic map of the Isobe district, modified after Oishi and Takahashi (1990). **C**. Fossil mollusc localities of the Haraichi and Itahana Formations along the Usui-gawa River.

sisting of conglomerate with frequent intercalation of lignite and coal layers; early Late Miocene age, based on diatoms (Yanagisawa and Akiba's NPD 5C); shallow-water molluscs partly abundant in lower unit; upper unit in non-marine origin with plant fossils.

Several authors have listed fossil molluscs from this area (e.g., Kanehara, 1938; Huzimoto and Kobayashi, 1938; Oinomikado, 1938; Ishiwada, 1948; Hoshino, 1952; Iwasaki, 1970). Among them, descriptive work was made only by Oinomikado (1938), who described some new species from the Itahana Formation. In this study, I describe fossil bivalves collected from of the Haratajino, Haraichi and Itahana Formations mainly in the Isobe district. The fossil localities of Haraichi and Itahana Formations are shown in Fig. 2A, C. For

those of the Haratajino Formation, see Kurihara (2000).

Iwadono area

The Iwadono area, Saitama Prefecture, is located at the eastern margin of the Kanto Mountains (Fig. 3). The Miocene formations and the Pre-Tertiary Sanbagawa metamorphic rocks are in fault contact. In the southern part of the area, the Miocene rocks are widely overlain by the Plio-Pleistocene Monomiyama Formation with unconformity (Koike *et al*., 1985; Majima, 1989). The Miocene sedimentary rocks developed in this area are divided by Kurihara *et al*. (2003) into the Arakawa, Godo, Negishi, Shogunzawa, Hatoyama and Imajuku Formations in ascending order with conformity, except that the relationship between the Arakawa and Godo Formations may be unconformity. Later, Takahashi and Yanagisawa (2004) revised the litho- and chronostratigraphy and defined the main part of the Godo Formation as the Ichinokawa Formation. The geologic age of the Miocene sequence in this area has become clarified by microfossil biostratigraphy (diatoms: Horiuchi and Yanagisawa, 1994; Takahashi and Yanagisawa, 2004; diatoms and calcareous nannofossils: Kurihara *et al*., 2003; planktonic foraminifers and calcareous nannofossils: Hayashi *et al*., 2003). The following brief description on the stratigraphy is based on Kurihara *et al*. (2003) and Takahashi and Yanagisawa (2004).

1) Arakawa Formation, at least 25 m thick, consisting of diatomaceous massive siltstone; biotur-

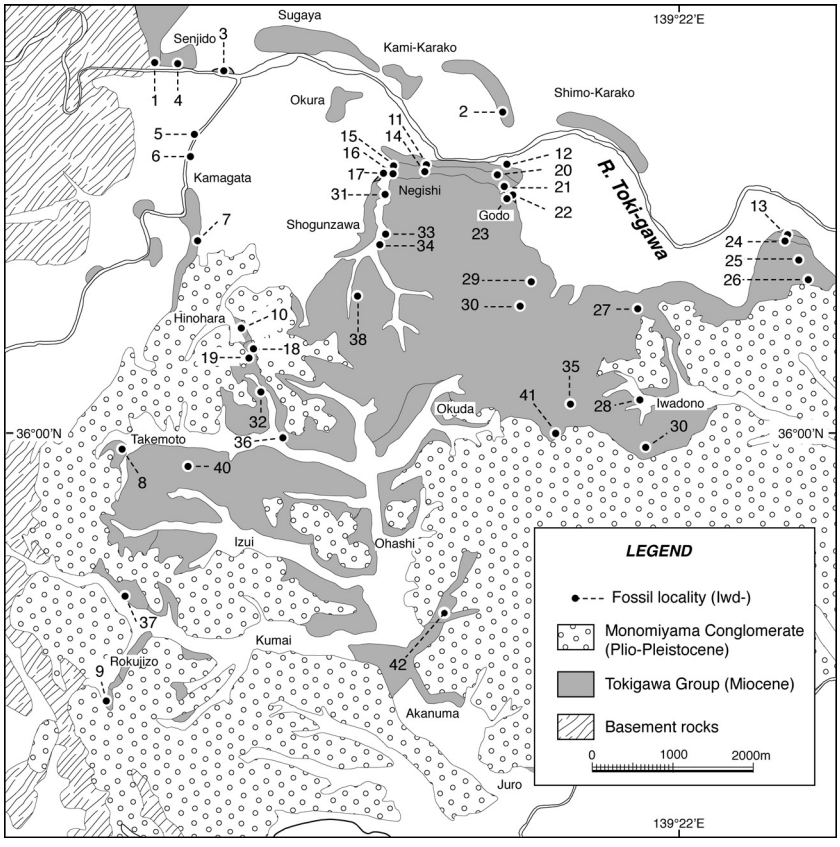


Fig. 3. Map showing fossil mollusc localities in the Iwadono area.

bation common; early Middle Miocene age, based on diatoms (Yanagisawa and Akiba's NPD 3A–4A); deep-water molluscs common, described by Kurihara (1999).

2) Ichinokawa Formation, about 200 m thick, consisting of diatomaceous sandy siltstone, sandstone with schist gravel, and poorly-sorted breccia; early Middle Miocene age, based on planktonic foraminifers (Blow's N.8); shallow-water molluscs rare.
3) Godo Formation, at least 15 m thick, base not observable but probably overlying the Ichinokawa Formation with unconformity; consisting of conglomerate and cross-bedded sandstone; middle Middle Miocene age, based on that of the overlying Negishi Formation; deep-water molluscs rare.
4) Negishi Formation, about 30 m thick, consisting of silty sandstone, coquinal sandstone, and felsic tuffs; bioturbation common; middle Middle Miocene age, based on planktonic foraminifers (Blow's N.10–N.10-13), calcareous nannofossils (Okada and Bukry's CN4–CN5a), and diatoms (Yanagisawa and Akiba's NPD 5B); deep-water molluscs common.
5) Shogunzawa Formation, about 350 m thick, consisting of diatomaceous massive siltstone and sandy siltstone, felsic tuffs; bioturbation common; middle to late Middle Miocene age, based on diatoms (Yanagisawa and Akiba's NPD 5B); deep-water molluscs rare.
6) Hatoyama Formation, about 200 m thick, consisting of alternation of sandstone and siltstone; early Late Miocene age based on diatoms (Yanagisawa and Akiba's NPD 5C); shallow-water molluscs very rare.
7) Imajuku Formation, more than 300 m thick, consisting of massive medium-grained sandstone and tuffaceous sandstone; no microfossils and molluscs found.

Some authors have listed fossil molluscs from this area (*e.g*., Kobayashi, 1935; Watanabe *et al*., 1950; Hatai and Masuda, 1962; Majima, 1989). Among them, Hatai and Masuda (1962) described some new species from the Tokigawa Formation [Negishi Formation]. In this study, I describe fossil bivalves from the Arakawa, Ichinokawa, Godo, Negishi, Shogunzawa and Hatoyama Formations. Fossil mollusc localities of this area are shown in Fig. 4.

Karasuyama area

The Karasuyama area, Tochigi Prefecture, is located in the western margin of the Yamizo Mountains, where Middle to Late Miocene Arakawa Group is well exposed along the Arakawa River (Fig. 4). The Arakawa Group overlies the Lower Miocene volcanic rocks of the Nakagawa Group unconformably in the eastern part, and is unconformably covered by the Pleistocene non-marine conglomerate of the Sakaibayashi Formation in the western part (Takahashi and Hoshi, 1996). The Arakawa Group is divided by Sakai (1986) into four units in ascending order: Kobana, Ogane, Tanokura and Irieno Formations with conformity. The geologic age of the Arakawa Group has become clear by microfossil biostratigraphy (planktonic foraminifers: Hayashi and Takahashi, 2000, 2002, 2004; calcareous nannofossils: Tanaka and Takahashi, 1998; diatoms: Yanagisawa, 2003) and by radiometric datings (Takahashi *et al*., 1999, 2000, Odin *et al*., 2001). The following brief description on the stratigraphy is based on Sakai (1986).

1) Kobana Formation, unconformably overlying the Miocene volcano-clastic Nakagawa Group, about 200 m thick, consisting of calcareous sandstone and sandy siltstone with basal conglomerate; early to middle Middle Miocene based on planktonic foraminifers (Blow'a N.8–N.10-13), calcareous nannofossils (Okada and Bukry's CN4–CN5a) and radiometric datings; shallow-water molluscs common.
2) Ogane Formation about 300 m thick, consisting of massive sandy siltstone and siltstone; late

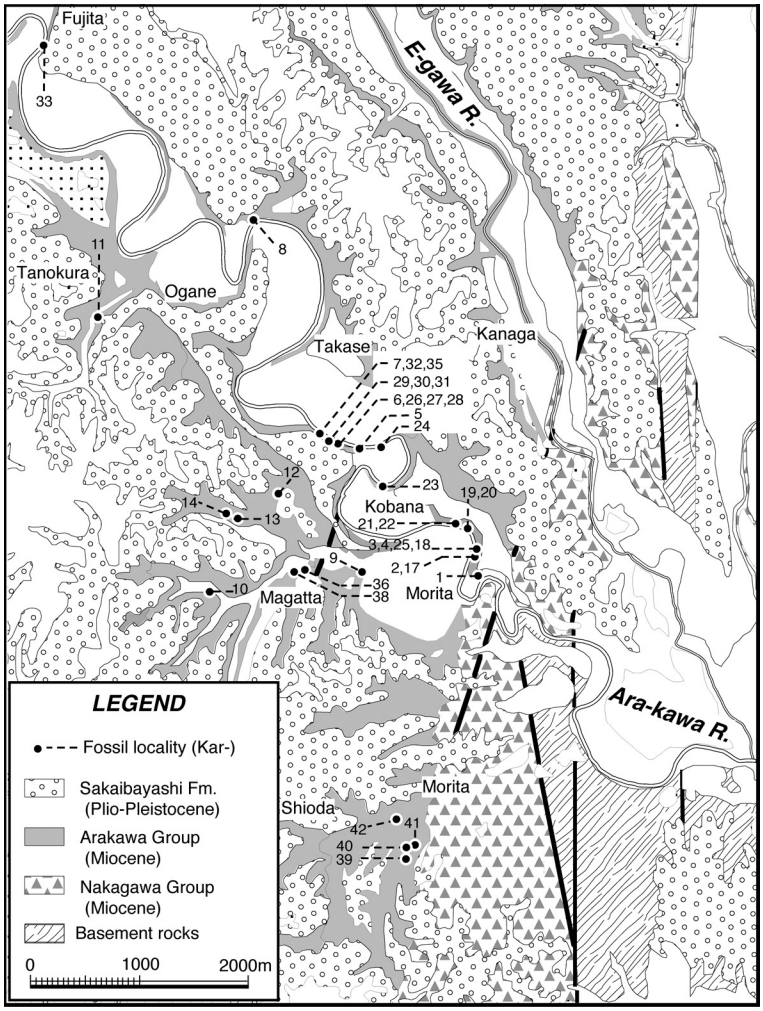


Fig. 4. Map showing fossil mollusc localities in the Karasuyama area.

Middle Miocene age based on planktonic foraminifers (Blow's N.14–N.16) and diatoms (Yanagisawa and Akiba's NPD 5C), shallow and deep-water molluscs common and locally abundant in sandstone beds called OGL, OGM and OGU by Sakai (1986).

3) Tanokura Formation about 210 m thick, consisting of diatomaceous mudstone; early Late Miocene age based on planktonic foraminifers (Blow's N.16), calcareous nannofossils (Okada and Bukry's CN7–CN8) and diatoms (Yanagisawa and Akiba's NPD 5C); deep-water molluscs rare.
4) Irieno Formation more than 50 m thick, consisting of fine-grained sandstone; early Late Miocene based on diatoms (Yanagisawa and Akiba's NPD 5D); molluscs not found in this study.

Some authors have listed fossil molluscs from this area (*e.g.*, Saka, 1946; Kawada, 1953; Hirayama, 1954, 1967; Furusawa *et al.*, 1987). Fossil molluscs from the Kobana and Ogane For-

mations were described by Hirayama (1954, 1967) and those from the Irieno Formation were described by Furusawa *et al*. (1987). In this study, I describe fossil bivalves collected from the Kobana, Ogane and Tanokura Formations in this area. Fossil mollusc localities are shown in Fig. 4.

Other areas

Bato area

The Bato area is located at Nakagawa-machi (formerly Bato-machi and Ogawa-machi), Tochigi Prefecture, immediate north of the Karasuyama area (Fig. 1). The geology of this area is still not well understood, but the localities discussed herein safely belong to the northern extension of the Arakawa Group distributed in the Karasuyama area (Fig. 5). The basal conglomerate of the Kobana Formation is also recognized in this area, and its lithology and faunal composition are almost same with those in the Karasuyama area. Stratigraphic position of fossilifeous very coarse-grained sandstone beds distributed along the Naka-gawa River at Yoshida (loc. Bat-3) is unclear, but the planktonic foraminiferal assemblage resembles that of the upper part of the Ogane Formation and the lower part of the Tanokura Formation (H. Hayashi, pers. comm.). As the molluscan fossil assemblage of this locality contains a species in common to the shell beds in the Ogane Formation, I tentatively treated this locality as belonging to the Ogane Formation.

Utsunomiya area

The Utsunomiya area, Tochigi Prefecture, is located between the Ashio and Yamizo Mountains (Fig. 1). Stratigraphic division of Miocene marine sequence in this area was recently revised by Takahashi and Yoshikawa (2008), who divided into the lower Oya and upper Ozo Formations with conformity. The geologic age of these formations have studied by planktonic foraminiferal biostratigraphy (Hayashi *et al*., 2004) and radiometric datings (Yoshikawa, 1998). The following brief description on the stratigraphy of the Utsunomiya Group is based on Takahashi and Yoshikawa (2008).

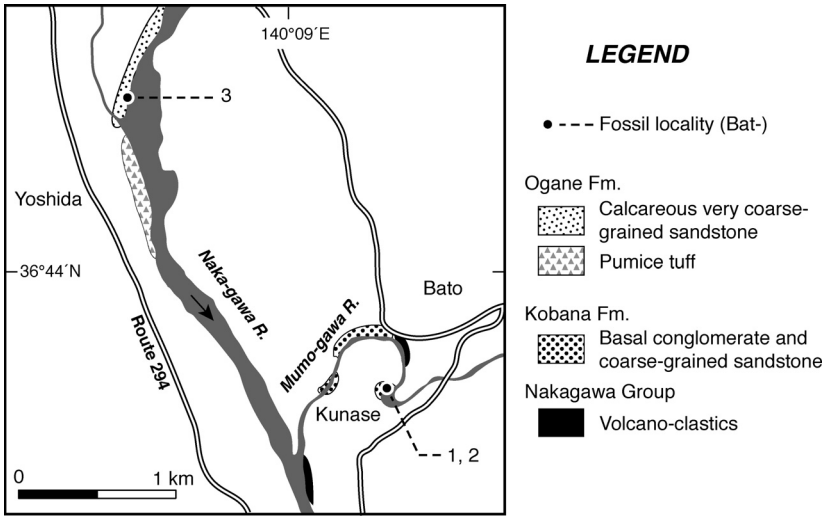


Fig. 5. Map showing fossil mollusc localities in the Bato area.

1) Oya Formation [redified; requivalent to the Yokoyama, Nagaoka and Yamamoto Formations of Akutsu, 1953; Hayashi *et al*., 2004], consisting of rhyolite lava, pumice tuff, sandstone and conglomerate; early Middle Miocene age based on planktonic foraminifers (Blow's N.8–9); shallow-water molluscs common; reported by Hayashi *et al*. (2004).
2) Ozo Formation, consisting of tuffaceous sandstone; middle Middle Miocene age based on planktonic foraminifers (Blow's N.9); molluscs rare.

Fossil molluscs from the Nagaoka Formation was listed by Masuda and Akutsu (1956), and those from the Ozo Formation were described by Akutsu (1960). In this study, I describe shallow-water molluscs collected from four localities (locs. Uts-1, 2, 3, 4) of the Oya Formation. These localities are not mapped herein. For details of the fossil mollusc localities, see Hayashi *et al*. (2004).

Joban area

The Joban area, ranging from northern Ibaraki to southern Fukushima Prefectures, is located at the eastern margin of the Abukuma Mountains. Neogene strata of the Joban area are divided by Yanagisawa (2002) into the Yunagaya, Shirado, Takaku, Taga Groups, in ascending order, with each unconformable contact. The Shimotezuna Formation is the lowermost unit of the Taga Group distributed in the Takahagi district. Diatom biostratigraphy of this formation was studied by Maruyama (1984) and Kurihara and Yanagisawa (2002). The following brief description of the stratigraphy of the Shimotezuna Formation is based on Kurihara and Yanagisawa (2002).

The Shimotezuna Formation, in fault contact with the Paleogene Shiramizu Group, and conformably underlain by the Kohama Formation; consisting of siltstone with basal conglomerate; lower to upper Middle Miocene age by diatoms (Yanagisawa and Akiba's NPD 5B); molluscs abundant in basal conglomerate.

In this study, I describe fossil bivalves collected from a single locality (loc. Nkg-1) of the Shimotezuna Formation. This locality is not mapped here. For details of the locality, see Kurihara and Yanagisawa (2002).

Kawamoto area

The Kawamoto area, Saitama Prefecture is located at the north of the Iwadono area (Fig. 1), where the Miocene Tsuchishio and Yagii Formations are developed along the Aarakawa River. The Tsuchishio Formation is in marine origin and fossiliferous and overlain by the non-marine Yagii Formation with conformity. Geologic age of the Tsuchishio Formation was determined by diatom biostratigraphy (Suto *et al*., 2002). The following brief description on the stratigraphy of the Tsuchishio Formation is based on Suto *et al*. (2003)

The Tsuchishio Formation at least 500 m thick, base not observable but probably in fault contact with Miocene rocks; consisting of diatomaceous siltstone, sandy siltstone and alternation of fine-grained sandstone and sandy siltstone with intercalation of tuffs beds; lower Upper Miocene age based on diatoms (Yanagisawa and Akiba's NPD 5C); molluscs common.

Shallow-water molluscs from the Tsuchishio formation were listed and partly illustrated by Hiki Research Group (1989). In this study, I describe fossil bivalves from one locality (Kmt-1) of the uppermost part of the Tsuchishio Formation. This locality, which is not mapped herein, is identical with "A-horizon" of Hiki Research Group (1989). For details of the locality, see Hiki

Research Group (1989).

Systematic descriptions

Format.—In the descriptions, the taxa I previously described or illustrated in my previous studies (Kurihara, 1999, 2000; Kurihara and Yanagisawa, 2002) are not discussed herein and only the synonymy and repository are indicated.

Repository.—The specimens described herein are housed in the Gunma Museum of Natural History, Tomioka, Gunma (GMNH), the Institute of Geoscience, the University of Tsukuba, Tsukuba (IGUT), and the Department of Geology and Paleontology, the National Museum of Nature and Science, Tokyo (NMNS).

Abbreviations.—The following abbreviations are used in the descriptions. RV=right valve; LV=left valve; CV=conjoined valves; L=shell length; H=shell height; W=shell width; Fm=Formation; Gr=Group.

Family Solemyidae H. and A. Adams, 1857
Genus ***Acharax*** Dall, 1908

Acharax gigas (Kanno, 1960)

Solemya (*Acharax*) *gigas* Kanno, 1960, p. 187–188, pl. 50, figs. 1, 2.

Acharax gigas (Kanno): Kurihara, 2000, p. 7–8, text-fig.5, pl. 1, figs. 3–5; pl. 2, figs. 1–2b; pl. 3, figs. 1a–2 [contains synonymies].

Material.—Eight specimens (GMNH PI338–344, 2000) from loc. Tom-HN1; two specimens (GMNH PI2050, 2051) from loc. Tom-2.

Occurrence.—Haratajino Fm., locs. Tom-2, HN1.

Acharax tokunagai (Yokoyama, 1925)

(Fig. 6P)

Solemya tokunagai Yokoyama, 1925a, p. 31, pl. 6, figs. 2.

Solemya (*Acharax*) *tokunagai* Yokoyama: Kamada and Hayasaka, 1959, p. 20–21, pl. 2, figs. 3, 4; Kamada, 1962, p. 37–39, pl. 1, fig. 2.

Solemya (*Acharax*) *tibai* Kuroda, 1948b, p. 29–32, text-figs. 1–3.

Acharax johnsoni (Dall): Habe, 1977, p. 12, pl. 1, fig. 5; Okutani *et al*., 1989, p. 22, 2 figs.; Okutani, 2000a, p. 833, pl. 414, fig. 1; Okutani *et al*., 2009, p. 198, Fig. 2A [not of Dall, 1891].

Material.—One specimen (NMNS PM25058) from loc. Tom-9; one specimen (NMNS PM25059) from Tom-31; one specimen (NMNS PM25060) from Tom-35; one specimen (IGUT 14368) from loc. Kar-30.

Remarks.—The largest specimen examined is from the Haraichi Formation and attains 110.0 mm long. The H/L ratio of the specimens examined ranges from 0.34 to 0.41. The specimens of *Acharax* from Lower and lower Middle Miocene of central Japan have a smaller shell size and more elongate shell outline, and they are tentatively distinguished from this species as *A*. sp. aff. *A. tokunagai* (Yokoyama) (Kurihara, 2000). As stated by Okutani *et al*. (2009), further studies are needed to clarify the taxonomic relationship between this Japanese species and *Acharax johnsoni* (Dall, 1891) from the eastern North Pacific.

Occurrence.—Haraichi Fm., locs. Tom-24, 3, 7, 26, 9, 31, 35, 41; Ogane Fm., loc. Kar-30; Tanokura Fm., loc. Kar-11.

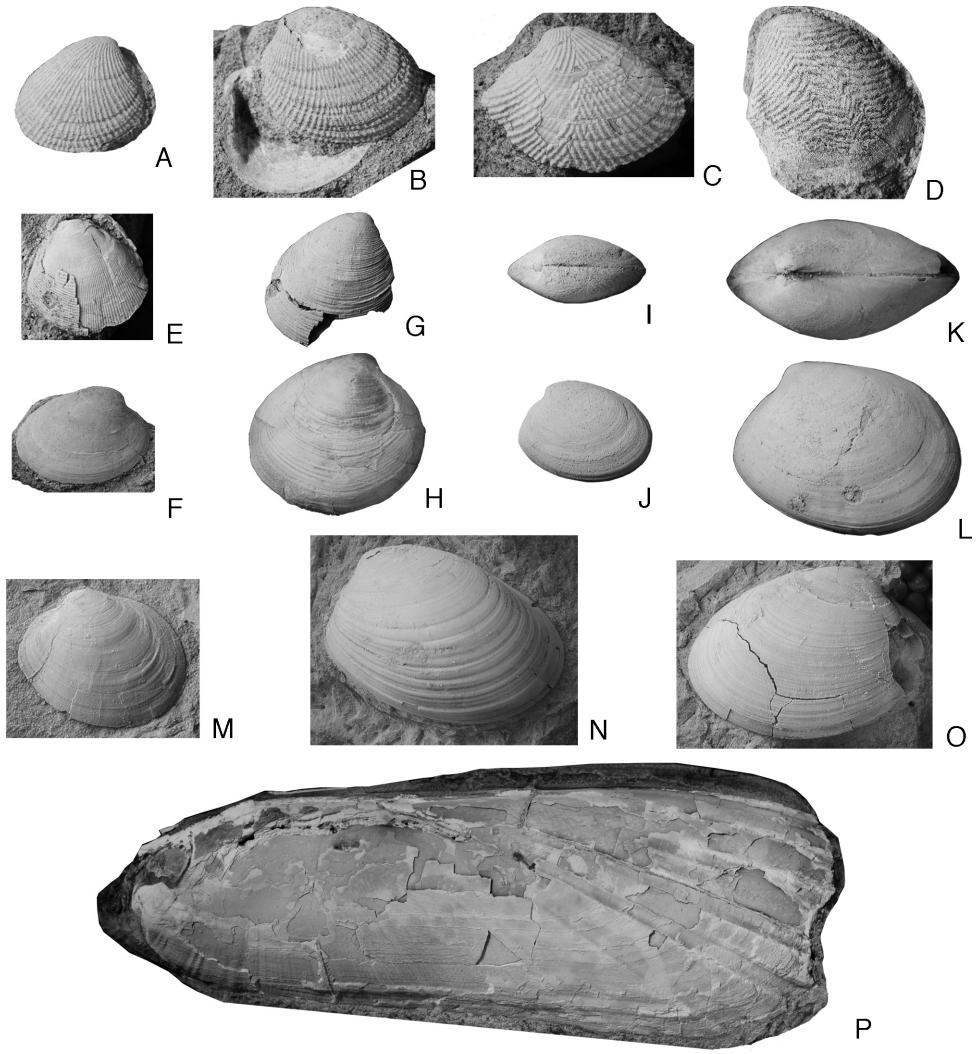


Fig. 6. **A, B**. *Acila* (*Truncacila*) *minutoides* Kuroda and Habe. A: CV, GMNH PI2054-3, 7.3×6.0×4.0 mm, loc. Tom-HN8, Itahana Fm. [left view (×2.5)]. B: RV, GMNH PI2054-1, 10.0×8.0×3.0 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2.5)]. **C**. *Acila* (*Acila*) *divaricata archibenthalis* Okutani. RV, NMNS PM25065, 13.5×9.3×3.4 mm, loc. Iwd-16, Negishi Fm. [exterior (×2)]. **D**. *Acila* (*Acila*) sp. cf. *A*. (*A*.) *yanagawaensis* (Nomura and Zinbo). RV, IGUT 14303, 22.0+×22.2 mm, loc. Kar-39, Kobana Fm. [internal mold (×1)]. **E**. *Lamellinucula hokoensis* (Kanehara). RV, NMNS PM25062, 5.7×5.3 mm, loc. Iwd-15, Negishi Fm. [exterior (×3)]. **F, I–O**. *Ennucula akitana* (Otuka). F: LV, NMNS PM25067, 11.7×8.5×3.2 mm, loc.Iwd-16, Negishi Fm. [exterior (×1.5)]. I, J: CV, GMNH PI2055, 12.4×9.0×6.0 mm, loc. Tom-HN8, Itahana Fm. [I: dorsal view, J: right view (×1.5)]. K, L: CV, GMNH PI2055, 20.8×17.0×10.6 mm, loc. Tom-HN8, Itahana Fm. [K: dorsal view, L: right view (×1.3)]. M: RV, NMNS PM25069, 14.7×12.5×3.2 mm, loc. Kmt-1, Tsuchishio Fm. [exterior (×1.5)]. N: RV, NMNS PM25070, 24.4×17.2×8.8 mm, loc. Kmt -1, Tsuchishio Fm. [exterior (×1.3)]. O: LV, NMNS PM25071, 25.0+×17.7×6.6 mm, loc. Kmt-1, Tsuchishio Fm. [exterior (×1.3)]. **G, H**. *Ennucula* sp. cf. *E. kokozuraensis* (Hatai and Nisiyama) comb. nov. G: LV, NMNS PM25074, 12.4+×13.0+ mm, loc. Iwd-16, Negishi Fm. [exterior (×1.5)]. H: CV, NMNS PM25073, 18.6×16.7×9.0 (×2) mm, loc. Tom-35, Haraichi Fm. [left view (×1.3)]. **P**. *Acharax tokunagai* (Yokoyama). CV, NMNS PM25058, 101.5×33.2 mm, loc. Tom-9, Haraichi Fm. [right view (×1)].

Stratigraphic and geographic range.—This species ranges from the upper Middle Miocene to Recent. Pliocene: Kurokura Fm., Niigata Pref.; Tomioka Fm., Fukushima Pref.; Hitachi Fm., Ibaraki Pref. Pleistocene: Tomikawa Fm., Hokkaido; Kakinokidai Fm., Chiba Pref.; Koshiba Fm., Kanagawa Pref. Recent: Northwestern Pacific south to Sagami Bay; 100–1,000 m deep.

Acharax sp. aff. ***A. tokunagai*** (Yokoyama, 1925)

Acharax aff. *tokunagai* (Yokoyama): Kurihara, 2000, p. 8, pl. 4, figs. 9, 13.

Material.—Four specimens (GMNH PI2016–2019) from loc. Tom-1.

Occurrence.—Haratajino Fm., locs. Tom-1, 19.

Family Nuculidae Gray, 1824

Genus ***Nucula*** Lamarck, 1799

Nucula sp.

Material.—One specimen (NMNS PM25061) from loc. Tom-45b.

Remarks.—A single incomplete valve of nuculid from the Itahana Formation is referable to *Nucula* Lamarck, 1799 by its small shell size (L 7.0 mm), ovate-subtrigonal shell outline, almost smooth external surface and crenulated inner ventral margin. This specimen is too poorly preserved to allow its specific identification.

Occurrence.—Itahana Fm., loc. Tom-45b.

Genus ***Lamellinucula*** Schenck, 1944

Lamellinucula hokoensis (Kanehara, 1936)

(Fig. 6E)

Nucula (*Nucula*) *hokoensis* Kanehara, 1936, p. 31–32, pl. 10, figs. 1, 2.
Lamellinucula hokoensis (Kanehara): Amano *et al*., 2004, fig. 3.1.

Material.—Four specimens (NMNS PM25062, 25063) from loc. Iwd-15.

Remarks.—The specimens examined are characterized by their small shell size (L＜7 mm), subtrigonal shell outline, irregular commarginal ribs as wide as the interspaces, and very fine radial striations. The inner ventral margin is finely crenulated. The escutcheon is narrow and defined by a shallow furrow extending from the beak to posterior margin. The lunule is indistinct. These characters well agree with those of *Lamellinucula hokoensis* (Kanehara, 1936). This species is distinguished from the Pliocene to Recent *Lamellinucula tokyoensis* (Yokoyama, 1920) by its semi-equilateral and proportionally higher shell outline and absence of distinct radial striations on the shell surface.

Occurrence.—Negishi Fm., locs. Iwd-15, 16.

Stratigraphic and geographic range.—This species was previously reported only from the lower Middle Miocene Ennichi Series, Korea and the Higashibessho Formation, Toyama Prefecture.

Genus ***Acila*** H. Adams and A. Adams, 1858
Subgenus ***Acila*** s. s.

Acila (***Acila***) sp. cf. ***A.*** (***A.***) ***yanagawaensis*** (Nomura and Zinbo, 1936)

(Fig. 6D)

Compare.—

Nucula (*Acila*) *yanagawaensis* Nomura and Zinbo, 1936a, p. 105–106, text-figs. 1a–2b.

Acila cf. *yanagawaensis* Nomura and Zinbo: Hirayama, 1954, p. 49, pl. 3, fig. 4.

Acila (*Acila*) *divaricata submirabilis* Makiyama: Ogasawara *et al*., 1986, pl. 1, figs. 2, 6, 7 [not of Makiyama, 1926].

Material.—One specimen (IGUT 14303) from loc. Kar-40.

Remarks.—The specimens examined is a single incompletely preserved internal mold. Although the shell is damaged, its subtrigonal outline and almost straight postero-dorsal margin agree well with those of *Acila* (*Acila*) *yanagawaensis* (Nomura and Zinbo, 1936). Although the specimen is considerably larger than the syntypes of *A.* (*A.*) *yanagawaensis* (the largest one, L 20.8 mm, H 17.0 mm), a specimen illustrated by Hirayama (1954) from the Kobana Formation is nearly identical with the largest syntype in size and form. Judging from the illustrations, *Acila* (*Acila*) *divaricata submirabilis* Makiyama, 1926 of Ogasawara *et al.* (1986) from the Yanagawa Formation is likely to be conspecific with *A*. (*A*.) *yanagawaensis*.

Occurrence.—Kobana Fm., loc. Kar-40.

Stratigraphic and geographic range.—*A.* (*A.*) *yanagawaensis* has been reported only from the lower Middle Miocene Yanagawa Formation, Fukushima Prefecture and Kobana Formation, Tochigi Prefecture.

Acila (***Acila***) sp. cf. ***A***. (***A***.) ***divaricata submirabilis*** Makiyama, 1926

Compare.—

Acila submirabilis Makiyama, 1926, p. 151–152, pl. 12, fig. 9.

Acila (*Acila*) *divaricata submirabilis* Makiyama: Noda *et al*., 1993, p. 125–126, figs. 12.13–12.15; Matsubara, 2004, p. 61–62, pl. 3, figs. 1–2b [contains synonymies].

Material.—One specimen (NMNS PM25064) from loc. Iwd-27.

Remarks.—Specimens of *Acila* collected from the Shogunzawa, Ogane, Tanokura and Tsuchishio Formations are all incomplete, but appear to be referable to *Acila* (*Acila*) *divaricata submirabilis* Makiyama, 1926 in their relatively large shell size (L>15 mm), subovate shell outline and widely convex postero-dorsal margin.

Occurrence.—Ogane Fm., locs. Kar-10, 19; Tanokura Fm., loc. Kar-33; Shogunzawa Fm., loc. Iwd-27; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—*A.* (*A.*) *divaricata submirabilis* ranges from the upper Lower Oligocene to Pleistocene of Japan and Korea (see Matsubara, 2004).

Acila (***Acila***) ***divaricata archibenthalis*** Okutani, 1964

(Fig. 6C)

Acila schencki archibenthalis Okutani, 1964, p. 81–82, pl. 6, fig.1.

Acila divaricata archibenthalis Okutani: Okutani *et al.*, 1989, p. 25, 2 figs.; Kurozumi and Tsuchida, 2000, p. 835, pl. 415, fig. 13.

Material.—One specimen (NSM PM25065) from loc. Iwd-16.

Remarks.—The specimen examined is referable to *Acila* (*Acila*) *divaricata archibenthalis* Okutani, 1964 as it is characterized by the small shell size (L＜15 mm), elongate and compressed shell outline, coarse divaricated radial ribs on the exterior surface, radially ribbed escutcheon and indistinct lunule. Okutani *et al*. (1989) considered that this subspecies is a deep-sea form of *Acila* (*Acila*) *divaricata divaricata* (Hinds, 1843).

Occurrence.—Negishi Fm., locs. Iwd-10, 15, 16, 22.

Stratigraphic and geographic range.—The Negishi specimens represent the first fossil record of this subspecies. In modern seas, this subspecies is known to occur at depths of 500–800 m from Sagami Bay to Tosa Bay (Kurozumi and Tsuchida, 2000).

Acila sp.

Acila sp.: Kurihara, 1999, table 2.

Occurrence.—Arakawa Fm., loc. Iwd-3.

Subgenus ***Truncacila*** U. S. Grant and Gale, 1931

Acila* (*Truncacila*) *minutoides Kuroda and Habe, 1958

(Fig. 6A, B)

Nucula insignis Gould: Yokoyama, 1920, p. 181, pl. 19, figs. 7–8c. [not of Gould, 1861]
Acila (*Truncacila*) *minutoides* Kuroda and Habe *in* Habe, 1958, p. 243–244; Kuroda *et al*., 1971, p. 504 [Japanese part], p. 317–318 [English part], pl. 66, fig. 7; Kurozumi and Tsuchida, 2000, p. 837, pl. 46, fig. 16.
Acila (*Acila*) *minutoides* Kuroda and Habe: Oyama, 1973, p. 74, pl. 20, figs. 26a–27.
Acila minutoides Kuroda and Habe: Baba, 1990, p. 228–229, pl. 22, fig. 9.

Material.—Four specimens (GMNH PI2101–2104) from loc. Tom-HN8; two specimens (NMNS PM25066) from loc. Tom-45b.

Remarks.—The specimens examined are characterized by their small shell size (L＜10 mm), ovate shell form, and finely divaricating exterior ornaments. These shell features strongly suggest that these specimens are referable to *Acila* (*Truncacila*) *minutoides* Kuroda and Habe, 1958. *Acila* (*Truncacila*) *insignis* (Gould, 1861), the most common species of *Truncacila* in Pliocene and Pleistocene strata of Honshu, is easily distinguished from this species by its larger shell size (L＞10 mm) and coarser exterior sculpture.

Occurrence.—Itahana Fm., locs. Tom-HN8, 45b.

Stratigraphic and geographic range.—This species ranges from the lower Upper Miocene to Holocene. Previous fossil records of this species have been reported from the Plio-Pleistocene Kazusa Group (Yokoyama, 1920; Oyama, 1973; Baba, 1990) in Chiba and Kanagawa Prefectures. Therefore, the Itahana specimens represent the oldest fossil record of this species. Modern occurrence of this species is reported in depths from 50 to 900 m, from off Boso Peninsula to Kyushu (Kurozumi and Tsuchida, 2000).

Genus ***Ennucula*** Iredale, 1931

Ennucula akitana (Otuka, 1943)

(Fig. 6F, I–O)

Nucula akitana Otuka, 1943, p. 230, pl. 3, figs. 1–3.

Ennucula akitana (Otuka): Itoigawa *et al*., 1981, pl. 1, figs. 5a, b; Itoigawa *et al*., 1982, p. 3–4.
Nucula (*Ennucula*) *osawanoensis* Tsuda, 1959, p. 67–68, pl. 1, figs. 1a, b.
Ennucula osawanoensis (Tsuda): Shibata *in* Itoigawa *et al*., 1974, p. 45–46, pl. 1, figs. 5a-8; Kaneko and Goto, 1997, p. 6, pl. 1, figs. 1a, b; Amano *et al.,* 2004, fig. 3.7.
Ennucula praenipponica Kamada, 1962, p. 42-43, pl. 1, figs. 8-11; Suehiro, 1979, p. 71–72, pl. 10, figs. 1a–c.

Material.—Eight specimens (GMNH PI2105–2112) from loc. Tom-HN8; three specimens (NMNS PM25067, 25068) from loc. Iwd-16; 10 specimens (NMNS PM25069–25072) from loc. Kmt-1.

Remarks.—A total of 21 well-preserved specimens of *Ennucula* were collected from the Negishi, Itahana and Tsuchishio Formations. They are considerably variable in the shell size and shape. The largest specimen (Fig. 5O), which was collected from the Tsuchishio Formation, is 25.0+ mm long, 17.7 mm high and 6.6 mm wide. The H/L ratio is 0.73–0.82 (average 0.79) in the Itahana specimens (n=4) and 0.71–0.86 (average 0.75) in the Tsuchishio specimens (n=3). As there is no remarkable morphological distinction in these specimens, I concluded that all the specimens belong to a single species, *Ennucula akitana* (Otuka, 1943), which was originally described from the Upper Miocene Kurosawa Formation, Akita Prefecture. On the basis of comparison with the topotypes, I regarded the following two Miocene species, *Ennucula osawanoensis* Tsuda, 1959 and *Ennucula praenipponica* Kamada, 1962, as junior synonyms of *E. akitana*. These species were said to differ from *E. akitana* in their slight differences in shell outline. The L/H ratio in the holotype of *E. akitana*, *E. osawanoensis* and *E. praenipponica* are 0.794, 0.771 and 0.773, respectively. The typical form of *E. akitana* is characterized by the relatively high shell, broadly convex antero-dorsal margin, and nearly straight postero-dorsal margin.

E. akitana is closely related to the Pliocene to Holocene *Ennucula niponica* (Smith, 1885), and its elongate shell form is almost identical to the latter. However, the two species differ in the number of hinge dentition. A specimen of *E. akitana* (L 12.0 mm, H 9.6 mm) from the Itahana Formation has 18 anterior and 7 posterior teeth, whereas a Holocene specimen of *E. niponica* from Sagami Bay (L 12.5 mm, H 9.2 mm) has 25 anterior and 10 posterior hinge teeth (Kuroda *et al*., 1971). The typical form of *E. akitana* resembles the modern *Ennucula tenuis* (Montagu, 1808) in shell outline but differs in having a larger shell size and less convex antero-dorsal margin.

Occurrence.—Itahana Fm., loc. Tom-HN8; Negishi Fm., locs. Iwd-6, 19, 22; Shogunzawa Fm., loc. Iwd-27; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—The fossil record of this species is restricted to the Miocene of Honshu. Upper Lower Miocene: Taira Fm., Fukushima Pref.; Akeyo and Oidawara Fms., Gifu Pref. Lower Middle Miocene: Kurosedani and Higashibessho Fms., Toyama Pref. Middle Miocene: Fujina Fm., Shimane Pref. Lower Upper Miocene: Kurosawa Fm., Akita Pref.

Ennucula sp. cf. ***E. kokozuraensis*** (Hatai and Nisiyama, 1949) comb. nov.

(Fig. 6G, H)

Compare.—
Nucula kokozuraensis Hatai and Nisiyama, 1949, p. 87, pl. 23, figs. 1–5.

Material.—One specimen (NMNS PM25073) from loc. Tom-35; one specimen (NMNS PM25074) from loc. Iwd-16; one specimen (NMNS PM25075) from loc. Iwd-22.

Remarks.—The specimens examined differ from *Ennucula akitana* (Otuka, 1943) in having distinct commarginal ribs on the shell exterior. These specimens are likely to be referable to

Nucula kokozuraensis Hatai and Nisiyama, 1949 in their almost equi-dimensional shell outline and exterior sculpture characteristic to that species. I transfer herein the generic assignment of this species to *Ennucula* Iredale, 1931 on the basis of a smooth inner ventral margin.

Occurrence.—Haraichi Fm., loc. Tom-35; Negishi Fm., locs. Iwd-16, 22.

Stratigraphic and geographic range.—*E. kokozuraensis* was previously reported only from the lower Middle Miocene Kokozura Formation, Ibaraki Prefecture.

Family Nuculanidae H. Adams and A. Adams, 1858
Genus ***Nuculana*** Link, 1807
Subgenus ***Thestyleda*** Iredale, 1929

Nuculana (***Thestyleda***) sp. aff. ***N***. (***T***.) ***kawamurai*** Habe, 1961

(Fig. 7B–D)

Compare.—

Nuculana kawamurai Habe, 1961, p. 109, app. 35, pl. 48, fig. 25.

Nuculana (*Thestyleda*) *kawamurai* Habe: Kurozumi and Tsuchida, 2000, p. 841, pl. 417, fig. 7; Okutani *et al*., 2009, p. 201, fig. 2N.

Material.—One specimen (NMNS PM25076) from loc. Tom-42; Four specimens (NMNS PM25077, 25078, 25079) from loc. Iwd-15.

Remarks.—The specimens examined are characterized by their small shell size (L＜14 mm), elongate shell form, truncate rostrum and fine commarginal ribs on the exterior surface. These shell features suggest that this species resembles *Nuculana* (*Thestyleda*) *kawamurai* Habe, 1961, a living species from bathyal depths of Kashima-Nada, central Japan. However, the present species differs slightly from *N. kawamurai* in having finer commarginal ribs.

Occurrence.—Itahana Fm., loc. Tom-42; Negishi Fm., loc. Iwd-15.

***Nuculana* (*Thestyleda*)** sp.

Nuculana (*Thestyleda*) sp.: Kurihara, 1999, fig. 6.16.

Material.—One specimen (IGUT 11838) from loc. Iwd-3.

Occurrence.—Arakawa Fm., loc. Iwd-3.

Subgenus ***Crassoleda*** Savizky, 1972

Nuculana* (*Crassoleda*) *pennula (Yokoyama, 1925)

Nuculana (*Crassoleda*) aff. *pennula* (Yokoyama): Kurihara, 1999, figs. 6.14, 6.15.

Nuculana (*Crassoleda*) *pennula* (Yokoyama): Kurihara, 2000, pl. 4, fig. 2 [contains synonymies].

Material.—One specimen (GMNH PI2027) from loc. Tom-1; one specimen (IGUT 11840) from loc. Iwd-2; one specimen (IGUT 11839) from loc. Iwd-3.

Occurrence.—Haratajino Fm., Tom-1; Arakawa Fm., locs. Iwd-2, 3.

Subgenus ***Tenuileda*** Habe, 1977

Nuculana (***Tenuileda***) ***ikebei*** (Suzuki and Kanehara, 1936)

(Fig. 7A)

Tenuileda cf. *ikebei* (Suzuki and Kanehara, 1936): Kurihara, 2000, pl. 4, fig. 10.
Poroleda ikebei (Suzuki and Kanehara): Kuroda *et al*., 1971, p. 511 [Japanese part], p. 322 [English part], pl. 66, fig. 21.
Tenuileda ikebei (Suzuki and Kanehara): Kurozumi and Tsuchida, 2000, p. 843, pl. 418, fig. 17.

Material.—Twelve specimens (NMNS PM25080, 25081) from loc. Iwd-22.

Remarks.—The specimens examined are referable to *Nuculana* (*Tenuileda*) *ikebei* (Suzuki and Kanehara, 1936) in their small shell size (L＜14 mm), compressed and elongate shell form, very gently curved rostrum, and a nearly smooth exterior surface.

Occurrence.—Haratajino Fm., loc. Tom-1; Negishi Fm., locs. Iwd-15, 22.

Stratigraphic and geographic range.—This species ranges from the lower Middle Miocene to Holocene on the Pacific side of central Honshu.

Genus ***Saccella*** Woodring, 1925

Saccella annakensis sp. nov.

(Fig. 7E-I)

Type specimen.—Holotype: GMNH PI2116.

Type locality, horizon and age.—Tom-HN8: right bank of the Usui-gawa River, Minakuchi, Annaka City, Gunma Prefecture (36°19′11″N, 138°53′12″E); lower part of the Itahana Formation; early Late Miocene.

Material.—In addition to the holotype, the following description is based on 16 paratypes (GMNH PI2113–2115, 2117–2124; NMNS PM25082–25086) from the type locality.

Diagnosis.—A *Saccella* with moderate-sized shell, submesially placed umbo, and dense, regular commarginal ribs that become obsolete near postero-dorsal margin.

Description.—Shell moderate in size for genus, rarely exceeding 17 mm in length, transversely elongate rhomboidal, moderately inflated, rather thin; antero-dorsal margin nearly straight; umbo placed near mid-length; lunule and escutcheon narrow, nearly smooth or weakly sculptured with radial lirae, delimited by a distinct sulcus extending from umbo to anterior and posterior ends, respectively; surface sculptured with densely and regularly developed commarginal ribs that become obsolete near postero-dorsal margin; number of hinge teeth about 20 anteriorly and 15 posteriorly in holotype.

Comparison.—This new species is very similar to *Saccella confusa* (Hanley, 1860), the most common species of *Saccella* in the Pleistocene and Holocene of central Japan. Both species are similar in shell form and size but are clearly distinguishable by the surface sculpture. *S. confusa* has coarser commarginal ribs allover the exterior surface (including lunule and escutcheon), whereas the new species has finer commarginal ribs that always become obsolete near the postero-dorsal margin, and almost smooth lunule and escutcheon.

Etymology.—Named after Annaka City, from which the all the type specimens were collected.

Occurrence.—Itahana Fm., locs. Tom-HN8, 41, 45a, 45b.

Stratigraphic and geographic range.—This new species is known only from the Itahana Formation.

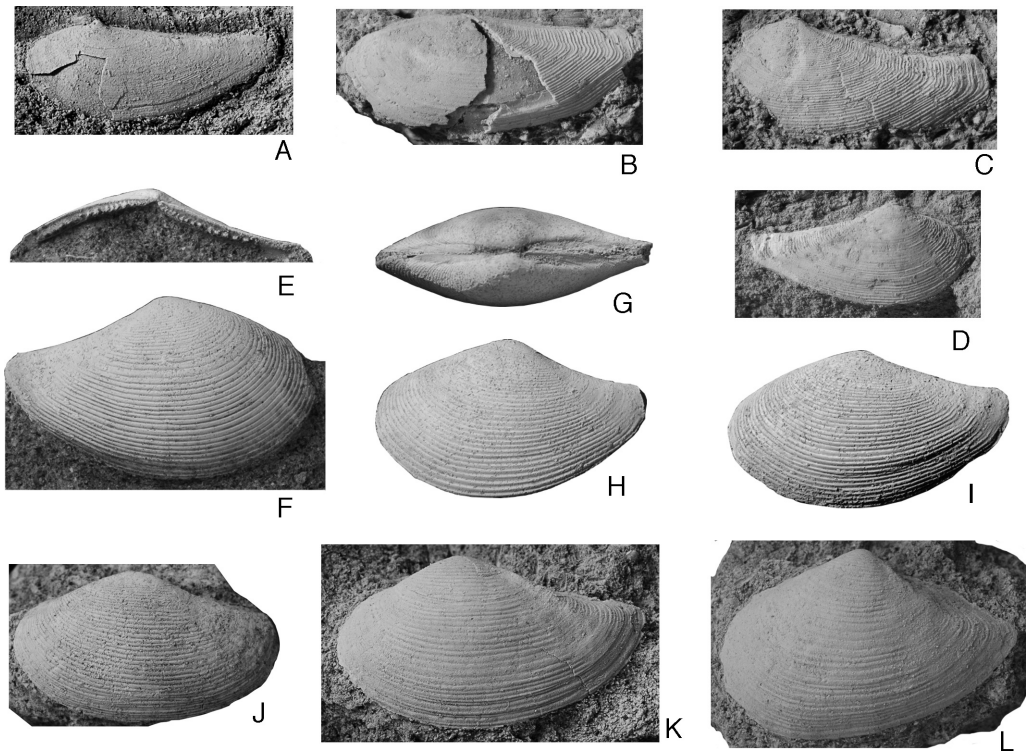


Fig. 7. **A**. *Nuculana* (*Tenuileda*) *ikebei* (Suzuki and Kanehara). LV, NMNS PM25080, 11.1×4.3×1.6 mm, loc. Iwd-22, Negishi Fm. [exterior (×3)]. **B–D**. *Nuculana* (*Thestyleda*) sp. aff. *N*. (*T*.) *kawamurai* Habe. B: LV, NMNS PM25077, 13.7+×5.0×2.0 mm, loc. Iwd-15, Negishi Fm. [exterior (×3)]. C: LV, NMNS PM25078, 11.8×5.0+ mm, loc. Iwd-15, Negishi Fm. [exterior (×3)]. D: RV, NMNS PM25076, 8.0×3.6 mm, loc. Tom-42, Itahana Fm. [exterior (×3)]. **E–I**. *Saccella annakensis* sp. nov. E, F: Holotype, RV, GMNH PI2116, 16.4×9.8×3.2 mm, loc. Tom-HN8, Itahana Fm. [E: hinge area; F: exterior (×2.5)]. G, H: Paratype, CV, GMNH PI2113, 15.0×8.7×5.2(×2) mm, loc. Tom-HN8, Itahana Fm. [G: dorsal view; H: left view (×2.5)]. I: Paratype, LV, GMNH PI2115, 15.3×8.5×3.3 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2.5)]. **J–L**. *Saccella konnoi* (Hatai and Masuda). J: LV, NMNS PM25087, 12.0×6.9×2.6 mm, loc. Iwd-22, Negishi Fm. [exterior (×3)]. K: LV, NMNS PM25088, 10.8×5.8×3.2 mm, loc. Iwd-22, Negishi Fm. [exterior (×4)]. L: LV, NMNS PM25089, 10.5×6.4×2.4 mm, loc. Iwd-22, Negishi Fm. [exterior (×4)].

Saccella konnoi (Hatai and Masuda, 1962)

(Fig. 7J–L)

Saccella konnoi Hatai and Masuda, 1962, p. 259–260, pl. 40, figs. 3–5.

Material.—Twelve specimens (NMNS PM25087–25090) from loc. Iwd-22.

Remarks.—The shell is rather small (commonly L<13 mm) and moderately inflated. The umbo is prominent and located at about two fifths of the length from the anterior margin. The exterior surface is ornamented by weak and irregular commarginal ribs which tend to be obsolete near both anterior and posterior margins. The escutcheon is defined by a ridge running from the beak to the posterior end. The internal characters are unknown.

This species resembles two Japanese Recent species, *Saccella husamaru* Nomura, 1940 and

S. kirai (Habe, 1953) in shell outline, but differs from the latter two species in having irregular and dorsally obsolete commarginal ribs.

Occurrence.—Kobana Fm., locs. Kar-39, 40; Negishi Fm., locs. Iwd-13U, 14, 15, 16, 22.

Stratigraphic and geographic range.—This species is known only from the middle Middle Miocene formations listed above.

Family Neilonellidae Allen, 1978
Genus ***Neilonella*** Dall, 1881

Neilonella isensis Shibata, 1970

Neilonella isensis Shibata: Kurihara, 1999, figs. 6.7a, b, 6.12 [contains synonymies]; Kurihara, 2000, p. 8–9, pl. 4, fig. 1.

Material.—Four specimens (GMNH PI2020) from loc. Tom-1; two specimens (IGUT 11832, 11833) from loc. Iwd-3.

Occurrence.—Haratajino Fm., locs. Tom-1, 19; Arakawa Fm., locs. Iwd-3.

Neilonella tsukigawaensis Kurihara, 1999

Neilonella tsukigawaensis Kurihara 1999, p. 232, figs. 6.8a–6.10b; Kurihara, 2000, p. 9, pl. 4, figs. 6, 7; Amano *et al*., 2004, fig. 3.3.

Material.—Four specimens (GMNH PI2021, 2022) from loc. Tom-1; three specimens (IGUT 11834) from loc. Iwd-3.

Occurrence.—Haratajino Fm., locs. Tom-1, 19; Arakawa Fm., locs. Iwd-3.

Stratigraphic and geographic range.—This species is restricted in the lower Middle Miocene of central Japan. Recently, Amano *et al*. (2004) recorded this species from the Miocene Kurosedani Formation, Toyama Prefecture.

Genus Malletiidae H. Adams and A. Adams, 1858
Genus ***Malletia*** des Moulins, 1832

Malletia inermis (Yokoyama, 1925)

(Fig. 8E, F)

Leda inermis Yokoyama, 1925b, p. 9, pl. 2, figs. 1–6.
Bathymalletia inermis (Yokoyama): Morita *et al*., 1996, p. 125–126, pl. 5, figs. 10, 11 [contains synonymies].
Malletia inermis (Yokoyama): Kurihara, 2000, p. 9, pl. 4, figs. 3–5; Amano *et al*., 2004, fig. 3.4.

Material.—Two specimens (IGUT 14369, 14370) from loc. Kar-33; nine specimens (NMNS PM25091) from loc. Kar-33.

Remarks.—The specimens examined were obtained from the Haratajino and Tanokura Formations. The largest specimen from the Tanokura Formation attains over 33 mm long, and a well-preserved specimen (Fig. 7F) has about 12 anterior and 30 posterior hinge teeth. As in the specimens illustrated by Yokoyama (1925b), this species shows a considerable variation in shell outline. The present specimens fall well within the variation of *Malletia inermis* (Yokoyama, 1925).

Occurrence: Haratajino Fm., loc. Tom-1; Tanokura Fm., locs. Kar-11, 33.

Stratigraphic and geographic range.—This species is restricted in the upper Lower Miocene to Lower Pliocene of central Japan (see Morita *et al.*, 1996).

Genus ***Bathymalletia*** Kuroda and Habe, 1971

Bathymalletia chitensis Shikama and Kase, 1976

Bathymalletia chitensis Shikama and Kase, 1976, p. 16, pl. 2, figs. 11, 12; Kurihara, 1999, fig. 6.13.

Material.—One specimen (IGUT 11836) from loc. Iwd-1.

Occurrence.—Arakawa Fm., loc. Iwd-1.

Bathymalletia sp.

(Fig. 8A)

Material.—One specimen (NMNS PM25092) from loc. Iwd-22.

Remarks.—The specimen examined is assignable to the genus *Bathymalletia* in having an umbonal-ventral keel characteristic for the genus. The specific identification is, however, difficult due to the incompleteness.

Occurrence.—Negishi Fm., loc. Iwd-22.

Family Yoldiidae Habe, 1977

Genus ***Portlandia*** Mörch, 1857

Subgenus ***Portlandia*** s. s.

Portlandia (***Portlandia***) ***japonica*** (A. Adams and Reeve, 1850)

(Fig. 8B–D, G–I)

Leda japonica A. Adams and Reeve, 1850, p. 75, pl. 21, fig. 9.

Yoldia japonica (A. Adams and Reeve): Yokoyama, 1928, p. 349, pl. 67, fig. 12.

Portlandia (*Portlandella*) *japonica* (A. Adams and Reeve): Kuroda *et al*., 1971, p. 512 [Japanese part], p. 322 [English part], pl. 66, fig. 12.

Portlandia japonica (A. Adams and Reeve): Hatai and Masuda, 1962, pl. 40, figs. 6, 7; Takahashi, 1986, pl. 12, fig. 5; Baba, 1990, p. 234, pl. 33, fig. 30; Kurozumi and Tsuchida, 2000, p. 845, pl. 420, fig. 33.

Material.—Seven specimens (GMNH PI2125–2131) from loc. Tom-HN8; two specimens (NMNS PM25093, 25094) from loc. Tom-42; one specimen (IGUT 143000) from loc. Tzk-1; 20 specimens (NMNS PM25095, 25096) from loc. Iwd-22; three specimens (NMNS PM25097, 25098) from loc. Kmt-1.

Remarks.—The largest specimen (Fig. 7H) is 19.0 mm long and 11.4 mm high. *Portlandia* (*Portlandia*) *lischkei* (Smith, 1885), an extant deep-water species, is closely allied to this species, but is distinguished from the latter by its larger shell size (L 21.7–29.9 mm; Kuroda *et al*., 1971) and pointed postero-dorsal corner.

Occurrence.—Itahana Fm., locs. Tom-HN8, 40, 42, 45b; Kobana Fm., loc. Tzk-1; Negishi Fm., locs. Iwd-16, 18, 20, 21, 22; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—The Negishi specimens represent the oldest fossil record of this species. This species ranges from middle Middle Miocene to Holocene. Lower Pliocene: Kume Fm., Ibaraki Pref.; Miyazaki Gr., Miyazaki Pref. Plio-Pleistocene: Kazusa Gr., Chiba Pref. This species is reported at depths of 20 to 300 m, from off Boso Peninsula to South China Sea (Kurozumi and Tsuchida, 2000).

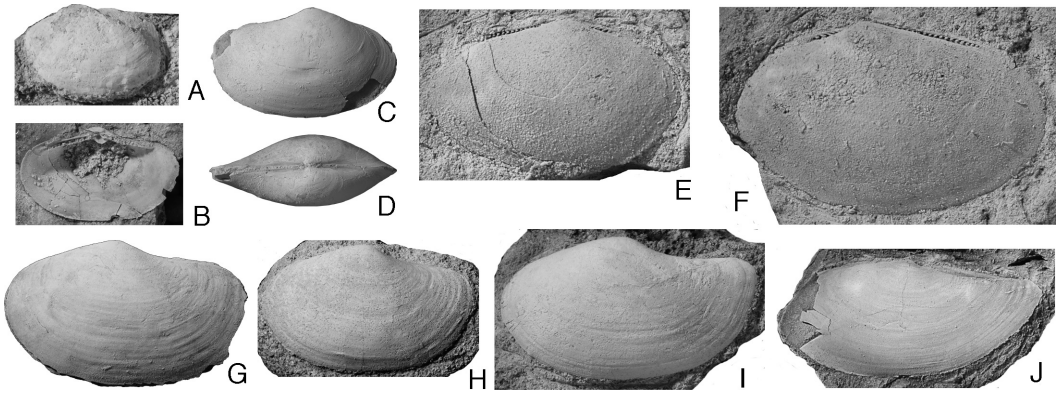


Fig. 8. **A**. *Bathymalletia* sp. LV, NMNS PM25092, 7.6×4.9×2.1 mm, loc. Iwd-22, Negishi Fm. [exterior (×2.5)]. **B–D, G–I**. *Portlandia* (*Portlandia*) *japonica* (A. Adams and Reeve). B: RV, NMNS PM25093, 14.2×8.4 mm, loc.Tom-42, Itahana Fm. [interior (×1.5)]. C, D: CV, GMNH PI2126, 16.4×9.4×6.0 (×2) mm, Itahana Fm.,×1.5 [C, left view; D, dorsal view (×1.5)]. G: CV, NMNS PM25097, 21.4×12.9×7.3 (×2) mm, loc. Kmt-1, Tsuchishio Fm. [a, right view; b, dorsal view (×1.5)]. H. LV, GMNH PI2125, 19.0×11.4 mm, loc. Tom-HN8, Itahana Fm. [exterior (×1.5)]. I: LV, NMNS PM25095, 23.3×12.9×4.7 mm, loc. Iwd-22, Negishi Fm. [exterior (×1.5)]. **E, F**. *Malletia inermis* (Yokoyama). E: RV, IGUT 14370, 17.4×11.3×2.4 mm. F: RV, IGUT 14369, 20.5×12.9×2.5 mm. loc. Kar-33, Tanokura Fm. [E, F, internal mold; (×2)]. **J**. *Yoldia* (*Yoldia*) sp. LV, NMNS PM25099, 24.5+×10.8×2.4 mm, loc. Kmt-1, Tsuchishio Fm. [exterior (×1.5)].

Subgenus ***Megayoldia*** Verrill and Bush, 1897

Portlandia (***Megayoldia***) ***thraciaeformis*** (Storer, 1838)

Nucula thraciaeformis Storer, 1838, p. 122, 1 text-fig.
Megayoldia thraciaeformis (Storer): Morita *et al*., 1996, p. 142–144, pl. 6, figs. 15, 18–20 [contains synonymies].
Portlandia (*Megayoldia*) *thraciaeformis* (Storer): Kurihara, 2000, pl. 4, figs. 16, 17.

Material.—Eighteen specimens (GMNH PI2029–2031) from loc. Tom-1; one specimen (IGUT 11841-1) from loc. Iwd-2.

Occurrence: Haratajino Fm., loc. Tom-1; Ogane Fm., locs. Kar-7, 32; Arakawa Fm., locs. Iwd-1, 2, 3.

Stratigraphic and geographic range.—*Portlandia* (*Megayoldia*) *thraciaeformis* (Storer, 1838) ranges from the Late Oligocene to Holocene in North Pacific regions (Morita *et al*., 1996; Coan *et al*., 2000) and also from the Pleistocene to Holocene in North Atlantic regions (Janse *et al*., 2002). Fossil occurrence of this species in the western Pacific region was summarized by Morita *et al.* (1996). In the North Pacific, this species is recorded at depths of 25–760 m in Low Arctic Ocean and circumboreal; northern Bering Sea, south to off San Francisco Bay, California; south to Sagami Bay (Coan *et al*., 2000).

Genus ***Yoldia*** Möller, 1842
Subgenus ***Yoldia*** s.s.

Yoldia (***Yoldia***) sp.

(Fig. 8J)

Material.—One specimen (NMNS PM25099) from loc. Kmt-1.

Remarks.—The specimen examined has a compressed shell, a pointed posterior end and almost smooth exterior shell surface. The umbo is located nearly at mid-length and less elevated above the dorsal margin. Specific identification is suspended until more complete specimens become available.

Occurrence.—Tsuchishio Fm., loc. Kmt-1.

Family Arcidae Lamarck, 1809
Subfamily Arcinae Lamarck, 1809
Genus ***Arca*** Linnaeus, 1758

Arca boucardi Jousseaume, 1894

(Fig. 9C)

Arca boucardi Jousseaume, 1894, p. 4, fig. 14.

Arca (*Arca*) *boucardi* Jousseaume: Noda, 1966, p. 55–56, pl. 6, figs. 12, 19 [contains synonymies]; Noda *et al*., 1993, p. 132, figs. 13.2a–b, 13.6; Matsukuma and Okutani, 2000, p. 847, pl. 421, fig. 4.

Material.—One specimen (GMNH PI2132) from loc. Tom-HN8.

Remarks.—This extant species is represented here by a single small right valve from the Itahana Formation. This species differs from a Pliocene species, *Arca miurensis* Noda, 1966, in having five or six distinct radial riblets on the posterior slope, instead of numerous fine radial riblets.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is reported in upper Lower Miocene to Holocene in Japan. Noda (1966) recorded this species from the Miocene Akeyo and Iwamura Formations, Gifu Prefecture, both of which are currently considered to be of late Early Miocene age. This species is known to occur at depths of intertidal zone to 50 m, southern Hokkaido to Okinawa (Matsukuma and Okutani, 2000).

Genus ***Acar*** Gray, 1857

Acar sp.

(Fig. 9B)

Acar sp.: Kurihara, 1999, table 2.

Material.—One specimen (NMNS PM25100) from loc. Iwd-10.

Remarks.—This unnamed species is represented by a single, poorly preserved left internal mold from the Negishi Formation. Its small shell size, elongate shell outline, very narrow ligamental area, and trace of rough cancellate pattern consisting of radial and commarginal ribs are characteristic of *Acar*. However, it is too poorly preserved to be specifically identified.

Occurrence.—Arakawa Fm., loc. Iwd-3; Negishi Fm., loc. Iwd-10.

Genus ***Bentharca*** Verrill and Bush, 1898

Bentharca takuroi Itoigawa and Shibata, 1975

(Fig. 9A)

Bentharca sp. (n. sp): Itoigawa *in* Itoigawa *et al*., 1974, p. 55, pl. 3, figs. 10–11b.

Bentharca takuroi Itoigawa and Shibata, 1975, p. 20–21, pl. 6, figs. 18a–20b; Itoigawa *et al*., 1981, pl. 2, figs. 6a, b; Itoigawa *et al*., 1982, p. 19–20.

Material.—One specimen (NMNS PM25101) from loc. Iwd-22.

Remarks.—This species is represented by a single left valve from the Negishi Formation. The specimen exhibits an elongate shell outline, a weak byssal notch and numerous radial threads crossed by commarginal lines on the exterior surface. These shell characters agree well with those of *Bentharca takuroi* Itoigawa and Shibata, 1975. This species differs from the Recent *Bentharca xenophoricola* (Kuroda, 1930) in its more elongated shell with a less expanded posterior part.

Occurrence.—Negishi Fm., loc. Iwd-22.

Stratigraphic and geographic range.—This species was previously reported only from the lower Middle Miocene Nataki Conglomerate Member of Oidawara Formation, Mizunami Group, Gifu Prefecture.

Subfamily Anadarinae Reinhart, 1935
Genus ***Anadara*** Gray, 1847
Subgenus ***Anadara*** s.s.

Anadara (***Anadara***) ***hataii*** Noda, 1966

(Fig. 9D, E, G–I)

Arca (*Anadara*) *ninohensis* Otuka: Nomura and Hatai, 1936, p. 119 [not of Otuka, 1934].
Anadara (*Anadara*) *ninohensis* (Otuka): Noda, 1966, pl. 9, figs. 14–18; Iwasaki, 1970, p. 389–393, pl. 2, figs. 1–4, pl. 3, figs. 1-5, pl. 5, fig. 9, pl. 7, figs. 1–3 [not of Otuka, 1934].
Anadara (*Anadara*) *hataii* Noda, 1966, p. 88-89, pl. 6, figs. 1, 4–7; Sasaki, 1990, figs. 15.1–15.4.

Materials.—Eleven specimens (GMNH PI2133–2143) from loc. Tom-HN8; one specimen (NMNS PM25102) from loc. Kmt-1.

Remarks.—The specimens examined are characterized by their moderate shell size (L<45 mm), well inflated shell form, and 28–32 granulated radial ribs that become bipartite when the shell height exceeds about 15 mm.

The taxonomy of *Anadara* in the Late Miocene Shiobara-type molluscan fauna has been controversial. Noda (1966) recognized three species in the Kubota Formation, Fukushima Prefecture, namely *A.* (*A.*) *hataii* Noda, 1966, *A.* (*A.*) *ninohensis* (Otuka, 1934) and *A.* (*A.*) *tanakuraensis* Noda, 1966. Later, Iwasaki (1970) concluded that these three species in the Kubota Formation are united into a single species *A. ninohensis,* originally described from the uppermost Lower Miocene Kadonosawa Formation in Iwate Prefecture. On the other hand, Sasaki (1990) concluded that the three *Anadara* species is not referred to true *A. ninohensis*, but belong to a single species, *A.* (*A.*) *hataii*, as a result of his biometric analysis. The Itahana and Tsuchishio specimens are identical to Sasaki's (1990) Type B of *A. hataii*, except for their small shell size.

Occurrence.—Itahana Fm., locs. Tom-HN8, 45a; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—This species is known to occur in Upper Miocene formations in Honshu.

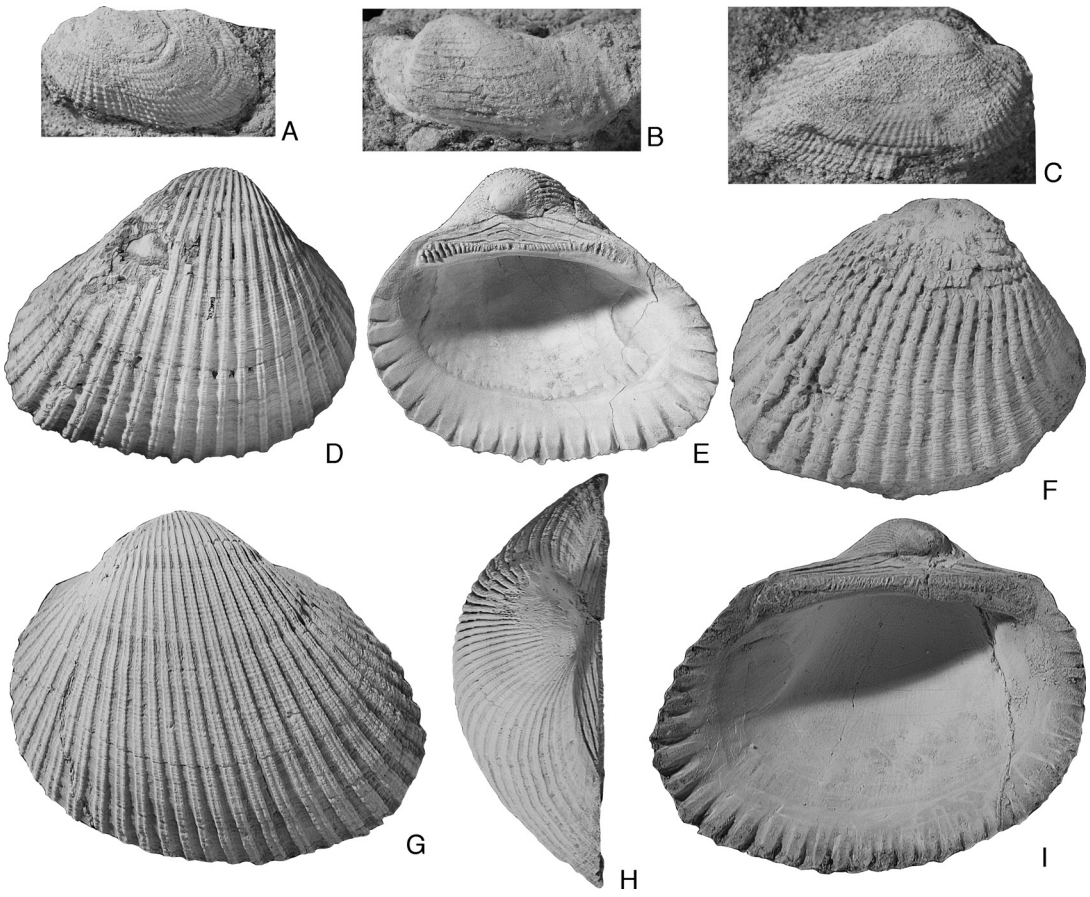


Fig. 9. **A**. *Bentharca takuroi* Itoigawa and Shibata. LV, NMNS PM25101, 6.4×4.0×1.7 mm, loc. Iwd-22, Negishi Fm. [exterior (×4.5)]. **B**. *Acar* sp. LV, NMNS PM25100, 11.8×5.6×2.9 mm, loc. Iwd-10, Negishi Fm. [exterior (×3)]. **C**. *Arca boucardi* Jousseaume. RV, GMNH PI2132, 18.9×10.2×5.0 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2)]. **D, E, G–I**. *Anadara* (*Anadara*) *hataii* Noda. D, E: RV, NMNS PM25102, 46.0×39.0×18.0 mm, loc. Kmt-1, Tsuchishio Fm. [D, exterior; E, interior (×1)]. G–I, RV, GMNH PI2133, loc. Tom-HN8, Itahana Fm. [G, exterior; H, dorsal view; I, interior (×1)]. **F.** *Anadara* (*Anadara*) sp. cf. *A*. (*A*.) *hataii* Noda. RV, IGUT 14360, 45.0×36.6 mm, loc. Kar-10, Ogane Fm. [exterior rubber cast (×1)].

Anadara (***Anadara***) sp. cf. ***hataii*** Noda, 1966

(Fig. 9F)

Anadara (*Tegillarca*) cf. *granosa bisenensis* Schenck and Reinhart: Hirayama, 1954, p. 50–51. [not of Schenck and Reinhart, 1938]

Material.—One specimen (IGUT 14360) from loc. Kar-10.

Remarks.—Mold specimens of *Anadara* occurs abundantly at the shell beds in the Ogane Formation, but it is difficult to collect complete external mold without any damages. The specimen examined shows at least 25 non-bipartite radial ribs as in the specimens of *Anadara* (*Anadara*) *hataii* Noda from the Kubota Formation (Noda, 1966). It is evidently identical to the specimen of *Anadara* from the Ogane Formation, which was illustrated by Hirayama (1954) as

Anadara (*Tegillarca*) cf. *granosa bisenensis* Schenck and Reinhart, 1938.

Occurrence.—Ogane Fm., locs. Kar-8, 10, 12, 13, 19, 14; Hatoyama Fm., loc. Iwad-42.

Family Glycymerididae Newton, 1916
Subfamily Glycymeridinae Newton, 1916
Genus ***Glycymeris*** da Costa, 1778
Subgenus ***Glycymeris*** s.s.

Glycymeris (***Glycymeris***) sp. aff. ***G.*** (***G.***) ***rotunda*** (Dunker, 1882)

(Fig. 10A–C)

Compare.—
Pectunculus rotundus Dunker, 1882, p. 236, pl. 16, figs. 9, 10.
Glycymeris rotunda (Dunker): Matsukuma, 2000a, p. 859, pl. 427, fig. 1.

Material.—One specimen (GMNH PI2060) from loc. Tom-HN8.

Remarks.—A single well-preserved left valve from the Itahana Formation was examined. It exhibits a circular, less inflated shell outline, about 50 primary radial costae and numerous fine secondary radial striations on the exterior surface, and distinctly grooved ligamental area. This species resembles the Late Miocene to Recent *Glycymeris* (*Glycymeris*) *rotunda* (Dunker, 1882) in general appearance, except for the circular shell outline. *G*. (*G*.) *rotunda* tends to exhibit a more obliquely elongate shell outline. Additional specimens are needed for its confirmed specific identification.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—*G.* (*G.*) *rotunda* ranges from the upper Upper Miocene to Recent (Okumura and Yamagishi, 1992). Its modern distribution range from southern Hokkaido to East China Sea at depths of 20–300 m (Matsukuma, 2000a).

Subgenus ***Veletuceta*** Iredale, 1931

Glycymeris (***Veletuceta***) ***cisshuensis*** Makiyama, 1926

(Fig. 10D–F)

Glycimeris [sic] *cisshuensis* Makiyama, 1926, p. 155–156, pl. 8, figs. 2, 3.
Glycymeris (*Veletuceta*) *cisshuensis* Makiyama: Matsukuma, 1986, p. 62–68, pl. 7, figs. 1, 3, 4, 6 [contains synonymies].
Glycymeris cf. *cisshuensis* Makiyama: Hayashi *et al*., 2004, table 2.
Glycymeris cf. *vestitoides* Nomura: Hayashi *et al*., 2004, table 2.
Glycymeris k-suzukii Oinomikado, 1938, p. 673–674, pl. 20, figs. 1–3.

Material.—Nineteen specimens (GMNH PI2145–2163) from loc. Tom-HN8.

Remarks.—This species is one of the well-known and common fossil glycymeridids in the Oligocene and Miocene of Japan. *Glycymeris k-suzukii* Oinomikado, 1938, originally described from the Itahana Formation, is currently believed to be a gerontic form of this species (Iwasaki, 1970; Matsukuma, 1986), to which I concur.

Occurrence.—Itahana Fm., loc. Tom-HN8; Oya Fm., locs. Uts-2b, 3.

Stratigraphic and geographic range.—This species is reported in the Lower Oligocene to Upper Miocene of Japan and Korea (see Matsukuma, 1986).

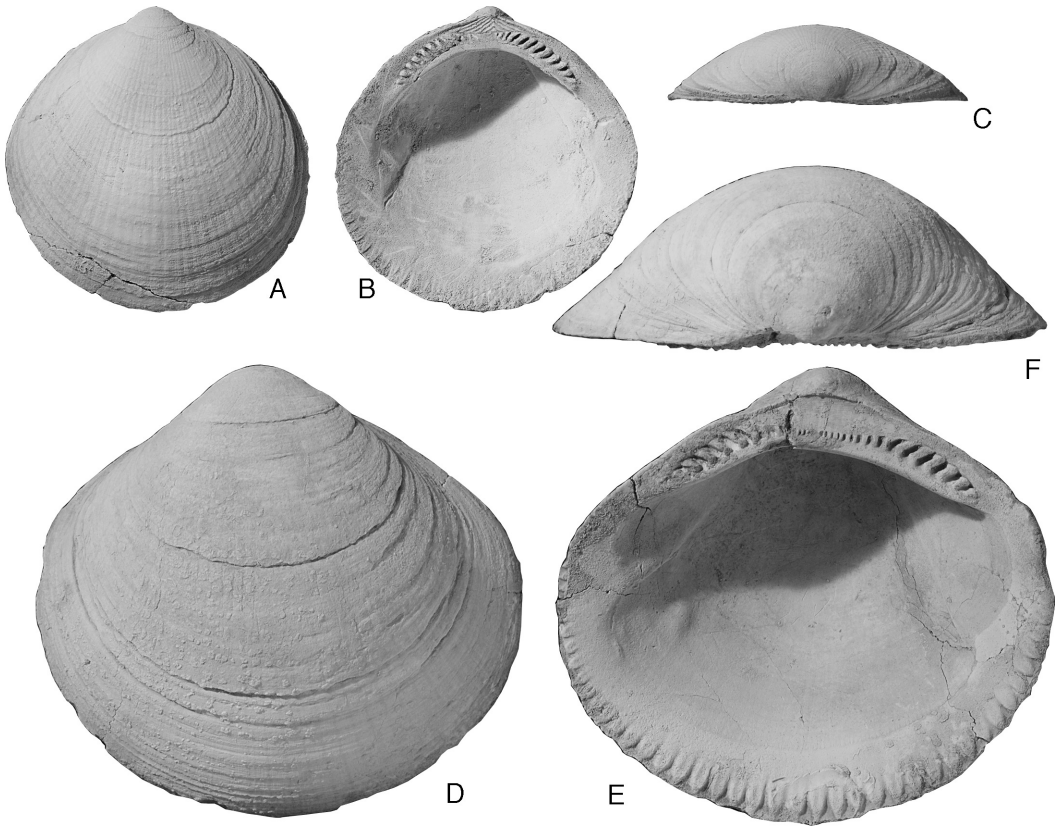


Fig. 10. **A–C**. *Glycymeris* (*Glycymeris*) sp. aff. *G.* (*G.*) *rotunda* (Dunker). RV, GMNH PI2144, 40.2×40.2×9.8 mm, loc.Tom-HN8, Itahana Fm. [A, exterior; B, interior; C, dorsal view (×1)]. **D–F.** *Glycymeris* (*Veletuceta*) *cisshuensis* Makiyama. LV, GMNH PI2145, 65.0×60.2×24.3 mm, loc.Tom-HN8, Itahana Fm. [D, exterior; E, interior; F, dorsal view (×1)].

Family Limopsidae Dall, 1895
Genus ***Limopsis*** Sassi, 1827

Limopsis nodai sp. nov.

(Fig. 11H–O)

Type specimen.—Holotype: NMNS PM15103.

Type locality, horizon and age.—Loc. Iwd-22: a small outcrop about 200 m SW of Myoshoji Temple at Goudo, Higashi-Matsuyama City, Saitama Prefecture (36°1′19″N, 139°20′45″E); lower part of the Negishi Formation; middle Middle Miocene.

Material.—In addition to the holotype, the following description is based on seven paratypes (NMNS PM15104–15110) from the type locality.

Diagnosis.—A *Limospsis* with moderate-sized, compressed shell, widely spaced radial costae on the exterior shell surface, relatively shorter ligamental pit and smooth inner ventral margin.

Description.—Shell moderate-sized for genus, rarely exceeding 25 mm long, weakly inflated (20–22% of length), slightly longer than high, obliquely ovate. Umbo small, low, situated at

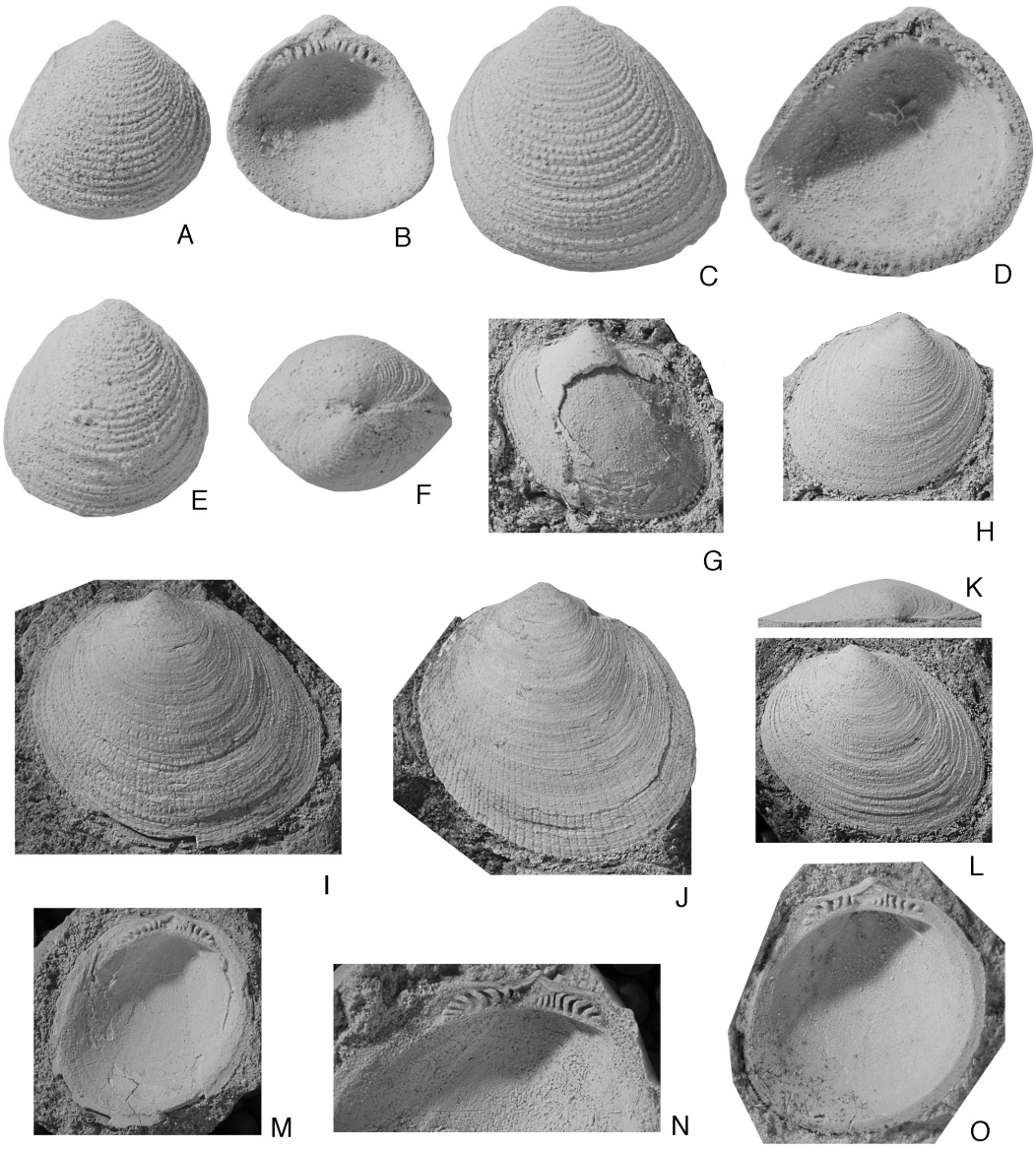


Fig. 11. **A–F**. *Limopsis nakajimai* sp. nov. A, B. Paratype, RV, GMNH PI2169, 6.8×6.8×2.4 mm [A, exterior; B, interior (×4)]. C, D. Holotype, LV, GMNH PI2165, 9.2×9.0×3.0 mm [C, exterior; D, interior (×4)]. E, F. Paratype, CV, GMNH PI2167, 6.8×7.3×5.1 (×2) mm [E, exterior; F, dorsal view (×4)]. All loc. Tom-HN8, Itahana Fm. **G**. *Limopsis* sp. LV, NMNS PM25111, 7.4×6.6×2.4 mm, loc.Iwd-15, Negishi Fm. [exterior (×4)]. **H–O**. *Limopsis nodai* sp. nov. H. Paratype, CV, NMNS PM25104, 9.2×7.9×2.4 mm [exterior (×2)]. I. Holotype, LV, NMNS PM25103, 20.0×18.0×4.0 mm [exterior (×2)]. J. Paratype, CV, NMNS PM25105, 20.0×19.4×4.4 mm, [exterior (×2)]. K, L. Paratype, LV, NMNS PM25106, 16.2×13.4×3.3 mm [K, dorsal view; L, exterior (×2)]. M. Paratype, LV, NMNS PM25107, 13.6+×14.2+ mm [interior (×2)]. N. Paratype, LV, NMNS PM25108, 15.4+×16.0+ mm [showing hinge plate, rubber cast (×3)]. O. Paratype, LV, NMNS PM25109, 11.5×11.2 mm [interior, rubber cast (×3)]. All loc. Iwd-22, Negishi Fm.

about anterior two-fifths of length. Exterior sculptured with very low, widely spaced radial costae and very low, widely spaced commarginal ridges. Inner ventral margin flat, relatively narrow, smooth. Hinge typical for genus, with 5–9 teeth in anterior series and 5–8 in posterior series, straight near center but curved or hooked at both ends, with short smooth section in center of larger specimens; width of ligamental pit 21–23% of hinge length.

Comparison.—This new species is most similar to the Plio-Pleistocene *Limopsis tokaiensis* Yokoyama, 1910 and the Pliocene to Recent *Limopsis uwadokoi* Oyama, 1951 in its shell form and covexity. However, *L. tokaiensis* and *L. uwadokoi* differ from the new species in having densely spaced radial costae and a wider ligamental pit (see Amano and Lutaenko, 2004). The Miocene *Limopsis osawanoensis* Tsuda, 1959 clearly differs from the new species in its smaller and more inflated shell and densely spaced radial costae. There is a possibility that this new species may be identical with a poorly known living species, *Limopsis obliqua* A. Adams, 1862, of which type material was recently illustrated by Higo *et al*. (2001) for the first time. Judging from the illustration and the remarks given by Habe (1953), however, *L. obliqua* differs from the new species in its well inflated shell.

Etymology.—In honor of Dr. Hiroshi Noda, a Professor Emeritus of the University of Tsukuba, who has greatly contributed to our knowledge of the Cenozoic molluscan paleontology in Japan and SE Asia.

Occurrence.—Kobana Fm., locs. Kar-39, 40; Negishi Fm., locs. Iwd-13U, 14, 15, 16, 20, 22; Shogunzawa Fm., loc. Iwd-27.

Stratigraphic and geographic range.—This species is known only from the localities mentioned above.

Limopsis nakajimai sp. nov.

(Fig. 11A–F)

Limopsis crenata A. Adams: Nomura and Hatai, 1936, p. 118, pl. 15, figs. 10, 11. [not of A. Adams, 1862]
Crenulilimopsis sp. cf. *C. oblonga* (A.Adams): Inoue *et al*., 1997, p. 116, figs. 5.2a, b. [not of A. Adams, 1860]

Type.—The holotype is a left valve (GMNH PI2164) from loc. Tom-HN8.

Type locality, horizon and age.—Tom-HN8: right bank of the Usui-gawa River, Minakuchi, Annaka City, Gunma Prefecture (36°19′11″N, 138°53′12″E); lower part of the Itahana Formation; early Late Miocene.

Material.—In addition to the holotype, the following description is based on six paratypes (GMNH PI2165–2170) from the type locality.

Diagnosis.—A *Limospsis* with small, subquadrate, well inflated shell, cancellate sculpture on the exterior shell surface and crenulated inner ventral margin except for postero-dorsal margin.

Description.—Shell small for genus, rarely exceeding 9 mm in length, roundly subquadrate, equivalve, inequilateral, rather thick, well inflated (32–38% of length); umbo small, located at middle of shell length; antero-dorsal margins nearly straight and short, gradually bending down to anterior and posterior margins; anterior margin rather narrowly convex, gradually bending down to widely convex ventral margin; posterior margin nearly straight and long, forming an acute postero-ventral corner. A distinct ridge running from umbo to postero-ventral corner, forming a flattened posterior slope. Exterior surface with cancellate sculpture, consisting of regular commarginal ridges and numerous beaded radial costae, except for almost smooth posterior slope. Inner ventral margin crenulated in accordance with radial costae, except for postero-dorsal

margin that is nearly smooth; crenulations strongest near postero-ventral corner and tend to obsolete anteriorly. Ligamental pit small and triangular in form. Hinge plate moderate in thickness with seven anterior and five posterior teeth.

Comparison.—*Limopsis oblonga* A. Adams, 1860, the most common species of *Limopsis* with crenulated inner ventral margin known in the Pliocene to Holocene of Japan, is distinguished from this new species by its rounded shell outline, widely spaced commarginal costae, finer crenulations developing whole inner ventral margin and by the absence of a posterior slope.

Judging from the description and illustration, *Limopsis crenata* of Nomura and Hatai (1936) from the Upper Miocene Tanagura bed [=Kubota Formation], Fukushima Prefecture, and *Crenulilimopsis* sp. cf. *C. oblonga* of Inoue *et al*. (1997) from the upper Middle Miocene Sugegaya Formation, Shizuoka Prefecture, may be conspecific with the new species.

Etymology.—Named after Mr. Hajime Nakajima, who collected and donated the type specimens to GMNH.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This new species is restricted in the upper Middle to lower Upper Miocene formations listed above in Honshu.

Limopsis sp.

(Fig. 11G)

Material.—One specimen (NMNS PM25111) from loc. Iwd-15.

Remarks.—A single, small left valve of *Limopsis* from the Negishi Formation clearly differs from *Limopsis nodai* sp nov. in having a distinct impression of fine crenulations on the inner ventral margin. Its specific identification is difficult due to the incompleteness.

Occurrence.—Negishi Fm., locs. Iwd-13U, 15.

Genus ***Nipponolimopsis*** Habe, 1951

Nipponolimopsis? sp.

Material—Two specimens (NMNS PM25112) from loc. Iwd-22.

Remarks.—The specimens examined are characterized by their small shell size (L<5 mm), strong shell convexity, obliquely elongate shell form, truncate antero-dorsal margin, and cancellate ornamentation on the exterior surface. These shell characteristics suggest that this species belongs to *Nipponolimopsis*. However, its specific identification is difficult due to its ill preservation.

Occurrence.—Negishi Fm., locs. Iwd-19, 22.

Family Mytilidae Rafinesque, 1815
Subfamily Mytilinae Rafinesque, 1815
Genus ***Crenomytilus*** Soot-Ryen, 1955

Crenomytilus grayanus (Dunker, 1853)

(Fig. 12E–G)

Mytilus Grayanus Dunker, 1853, p. 84–85.

Crenomytilus grayanus (Dunker): Soot-Ryen, 1955, pl. 2, figs. 9, 10; Noda *et al*., 1993, p. 137–138, fig. 15.10 [contains synonymies].

Mytilus (*Crenomytilus*) *grayanus* (Dunker): Kurozumi, 2000, p. 863, pl. 429, fig. 4.

Crenomytilus aff. *grayanus* (Dunker): Hayashi *et al*., 2004, table 2.

Material.—One specimen (GMNH PI2057) from loc. Tom-HN7; one specimen (GMNH PI2171) from loc. Tom-HN8; two specimens (NMNS PM25113, 25114) from loc. Uts-2A.

Remarks.—The specimens examined are all incomplete. They attain a very large size (max. L>180 mm) and show a delicate exterior ornamentation with very fine radial striations characteristic of *Crenomytilus* Soot-Ryen, 1955. *Crenomytilus grayanus* (Dunker, 1853), the only living species and the type species of the genus, shows a rather wide range of variation in shell form, to which the present specimens are included. Vermeij (1989) suggested that several nominal species of *Crenomytilus* from the Upper Miocene and Pliocene formations in California may be synonymous with *C. grayanus*, but this needs further investigation.

Occurrence.—Haraichi Fm., loc. Tom-HN7; Itahana Fm., loc. Tom-HN8; Oya Fm., locs. Uts-1, 2a, 2b.

Stratigraphic and geographic range.—This species was previously reported from Upper Miocene to Pleistocene formations in central Honshu to Hokkaido. The specimens from the Oya Formation may represent the oldest fossil record of the species. This species is currently distributed in intertidal zone to a depth of 50 m, northern Honshu to Hokkaido (Kurozumi, 2000).

Subfamily Crenellinae J. E. Gray, 1840

Genus ***Crenella*** Brown, 1827

Crenella yokoyamai Nomura, 1932

(Fig. 12A–C)

Crenella divaricata Yokoyama, 1922, p. 175–176, pl. 15, figs. 10, 11 [not of d'Orbigny, 1847].

Crenella yokoyamai Nomura, 1932, p. 74; Baba, 1990, p. 248, pl. 25, fig. 3 [contains synonymies]; Kurozumi, 2000, p. 871, pl. 434, fig. 46.

Material.—Five specimens (NMNS PM25115) from loc. Iwd-13U; six specimens (NMNS PM25116) from loc. Iwd-15; fourteen specimens (NMNS PM25117–25120) from loc. Iwd-22.

Remarks.—The shell is small (H<10 mm), orbicular, slightly higher than long, very thin, and well-inflated. The beak is prominent, slightly prosogyrate and is located about half of the length. The exterior surface is entirely sculptured by numerous radial threads. The commarginal lines are developed around the beak. These shell characteristics agree well with those of the extant *Crenella yokoyamai* Nomura, 1932.

Occurrence.—Negishi Fm., locs. Iwad-13U, 14, 15, 16, 18, 19, 22.

Stratigraphic and geographic range.—The fossil specimens of this species was previously reported only from Plio-Pleistocene formations of central and northern Honshu (Baba, 1990). The specimens from the Negishi Formation represent the oldest fossil record of this species. Modern forms are known to occur in sandy bottoms at depths of 30–300 m, Sagami Bay to the Bering Sea (Kurozumi, 2000).

Genus ***Solamen*** Iredale, 1924

Solamen sp. cf. ***S. columbiana*** (Dall, 1897)

(Fig. 12D)

Compare.—

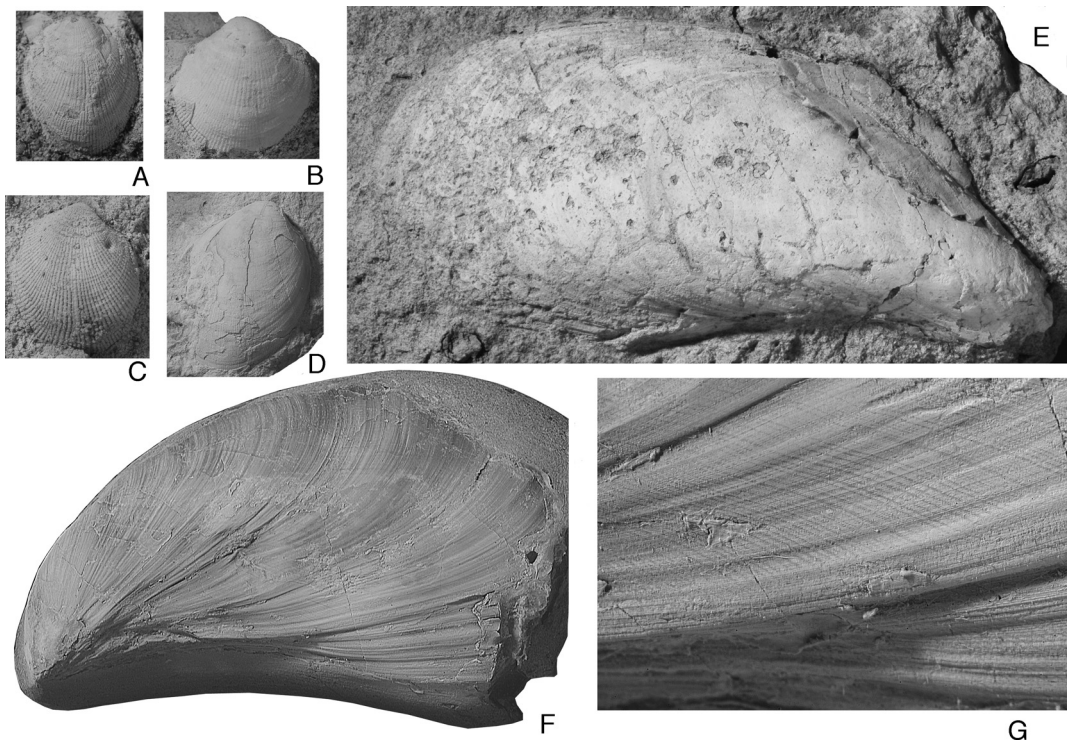


Fig. 12. **A–C**. *Crenella yokoyamai* Nomura. A: LV, NMNS PM25117, 6.5×8.0 mm [exterior (×2.5)]. B: LV, NMNS PM25118, 8.0×7.3 mm [exterior (×2.5)].C: RV, NMNS PM25119, 6.8×7.0 mm [exterior, rubber cast (×3)]. All loc. Iwd-22, Negishi Fm. **D**. *Solamen* sp. cf. *S. columbiana* (Dall). LV, NMNS PM25121, 14.6+×19.1×6.8 mm, loc.Tom-5, Haraichi Fm. [exterior (×1.2)]. **E–G**. *Crenomytilus grayanus* (Dunker). E: RV, NMNS PM25113, 184.0×87.0 mm, loc. Uts-2A, Oya Fm. [internal mold with shell fragments (×0.5)]. F, G: LV, GMNH PI2171, loc. Tom-HN8, Itahana Fm. [F, exterior (×0.7); G, enlarged view of exterior showing fine radial striae (×6)].

Crenella columbiana Dall, 1897, p. 4, pl. 1, figs. 3, 5.
Solamen columbiana (Dall): Soot-Ryen, 1955, p. 82–83, pl. 8, fig. 46; Coan *et al*., 2000, p. 171, pl. 25.
Megacrenella columbiana (Dall): Kurozumi, 2000, p. 871–872, pl. 434, fig. 49.

Material.—One specimen (NMNS PM25121) from the loc.Tom-5.

Remarks: This species is represented by a single incomplete right valve from the Haraichi Formation. The shell is large (L 14.6 mm, H 19.1 mm), well inflated and ovate in form, and the partly preserved shell suggests that the exterior surface is covered with very fine radial striations. These shell characteristics suggest that this species is related to the Recent *Solamen columbiana* (Dall, 1897).

Occurrence: Haraichi Fm., loc. Tom-5.

Stratigraphic and geographic range.—Nagamori (1998) listed *S. columbiana* from the Pliocene Shigarami Formation of Nagano Prefecture, central Japan. There is no reliable Miocene record of this species. This species is known to occur at depths of 20–500 m from Hokkaido, Siberia, Alaska to California (Kurozumi, 2000; Coan *et al*., 2000).

Family Limidae Rafinesque, 1815
Genus ***Lima*** Bruguière, 1797

Lima sp. A

(Fig. 13D)

Material.—One specimen (NMNS PM25122) from loc. Iwd-18.

Remarks.—A single imperfect left valve from the Negishi Formation may attain 10 mm in height and bears about 21 distinct radial ribs. Detailed identification is difficult because these shells are too poorly preserved.

Occurrence.—Negishi Fm., loc. Iwd-18.

Lima sp. B

Material.—Two specimens (NMNS PM25123) from loc. Iwd-19.

Remarks.—This unnamed species is represented by two poorly preserved specimens from the Negishi Formation. They are characterized by its rather small shell size (H<15 mm) and about 30 distinct radial ribs on the exterior surface, small auricles, and large umbonal angle. Its preservation is too poor to allow specific identification.

Occurrence.—Negishi Fm., loc. Iwd-19.

Genus ***Acesta*** H. Adams and A. Adams, 1858
Subgenus ***Acesta*** s. s.

Acesta* (*Acesta*) *goliath (Sowerby, 1883)

(Fig. 13E)

Lima goliath Sowerby, 1883, p. 30, pl. 7, fig. 3.
Acesta goliath (Sowerby): Baba, 1990, p. 259–260, pl. 29, fig. 1 [contains synonymies]; Hayami, 2000a, p. 891, pl. 443, fig. 9; Amano *et al*., 2004, fig. 3.19.

Material.—Three specimens (GMNH PI2057–2059) from loc. Tom-HN7.

Remarks.—The specimens examined are all conjoined. They are referable to *Acesta* (*Acesta*) *goliath* (Sowerby, 1883) in their large shell size (L, H>100 mm), subovate shell form and the presence of radial striations on the exterior surface near anterior and posterior ends.

Occurrence.—Haraichi Fm., loc. Tom-HN7.

Stratigraphic and geographic range.—This species ranges from the uppermost Lower Miocene to Holocene in Japan (Baba, 1990; Amano, 2004), and known to occur at depths of 100–1400 m, southern Hokkaido to Sagami Bay (Hayami, 2000a).

***Acesta* (*Acesta*)** sp.

(Fig. 13F)

Acesta goliath (Sowerby): Majima, 1989, fig. 12.5 [not of Sowerby, 1883].

Material.—Six specimens (NMNS PM25124, 25125) from loc. Iwd-13U.

Remarks.—The specimens examined closely resemble *Acesta* (*Acesta*) *goliath* (Sowerby, 1883) in the general shell characteristics, but differ in their smaller shell size (L, H<100 mm) and the presence of weak, somewhat wavy radial riblets allover the exterior surface. Although

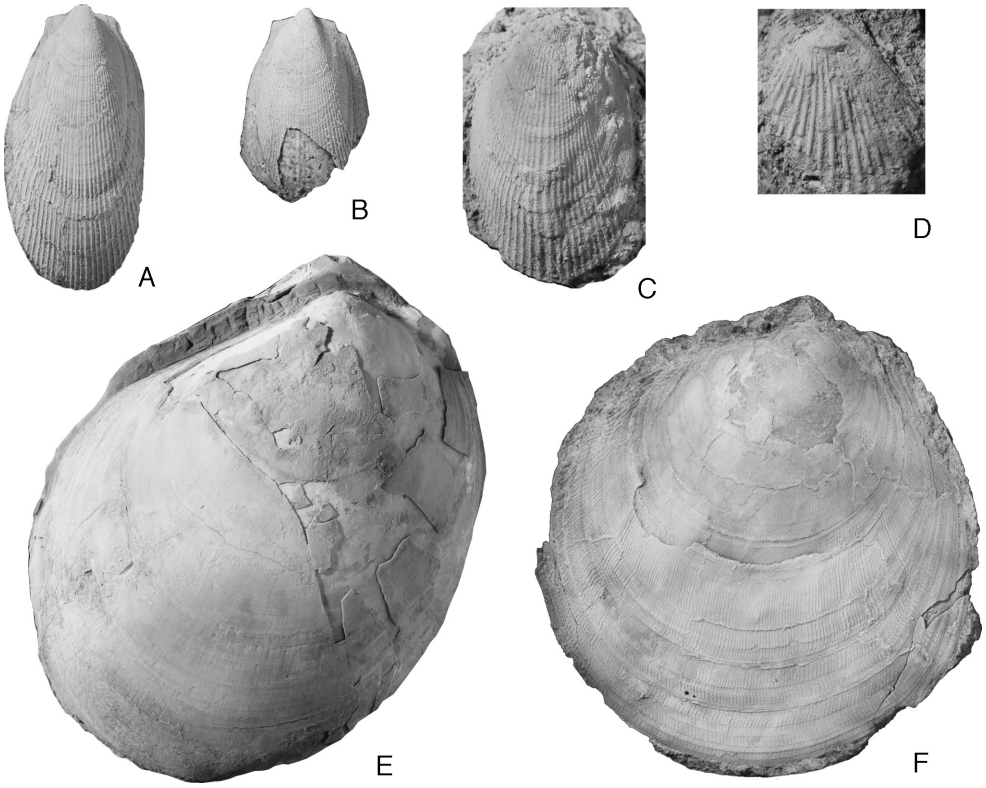


Fig. 13. **A, B**. *Limatula* (*Limatula*) *blenda* Ozaki. A: LV, GMNH PI2172, 6.0×12.6×ca. 3.2 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2.5)]. B: LV, GMNH PI2173, 6.0×8.8+×3.0 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2.5)]. **C**. *Limatula* (*Limatula*) sp. LV, NMNS PM25126, 5.8×9.1+×3.0 mm, loc. Iwd-22, Negishi Fm. [exterior (×2.5)]. **D**. *Lima* sp. A. LV, NMNS PM25122, 8.0+×7.0+ mm, loc. Iwd-18, Negishi Fm. [exterior (×2.5)]. **E**. *Acesta* (*Acesta*) *goliath* (Sowerby). CV, GMNH PI2144, 120.0×120.0 mm, loc. Tom-HN7, Haraichi Fm. [right view (×0.5)]. **F**. *Acesta* (*Acesta*) sp. CV, NMNS PM25124, 58.6+×59.4 mm, loc. Iwd-13U, Negishi Fm. [right view (×1)].

they may be juvenile specimens of *A*. (*A*.) *goliath*, they do not co-occur with typical large specimens of *A*. (*A*.) *goliath*. Therefore, they are tentatively treated as an unnamed species herein.

Occurrence.—Negishi Fm., locs. Iwd-10, 13L, 13U, 15, 16, 18, 19, 20, 22, 24; Kobana Fm., loc. Kar-39.

Genus ***Limatula*** Wood, 1839
Subgenus ***Limatula*** s.s.

Limatula* (*Limatula*) *blenda Ozaki, 1956

(Fig. 13A, B)

Limatula subauriculata blanda Ozaki, 1956, p. 5, pl. 1, fig. 14.

Material.—Three specimens (GMNH PI2172–2174) from loc. Tom-HN8.

Remarks.—The shell is large for genus (H<13 mm), longitudinally elongated, and moderately inflate. The exterior surface is covered with more than 40 distinct radial threads that are nar-

rower than their interspaces and become obsolete toward the anterior and posterior margins. The interior surface is smooth and has two very weak radial grooves that are centrally developed in the shell center. The hinge plate is weak, and the ligamental pit is rather large and trigonal in form.

This species is characterized by its proportionally higher shell outline and more than 40 radial threads on the exterior surface. The H/L ratio ranges from 2.04 to 2.10 in the Itahana specimens. These characters agree well with those of *Limatula* (*Limatula*) *blenda* Ozaki, 1956.

This species resembles *Limatula vladivostokensis* Scarlato, 1955, a common Pliocene to Holocene species of *Limatula* in central Japan and further north, in general shell characteristics, but clearly differs from the latter in the exterior ornament and the H/L ratio. According to Scarlato (1981), *L. vladivostokensis* has only 20–32 threads and the H/L ratio is 1.73. *L. choshiensis* Kuroda and Habe, 1961 from bathyal depths of Sagami Bay and off Choshi is also clearly distinguished from the present species in its lower shell outline.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic distribution.—This species was previously recorded only from the Pliocene Nobori Formation, Kochi Prefecture. The specimens from the Itahana Formation represent the oldest fossil record of this species.

***Limatula* (*Limatula*)** sp.

(Fig. 13C)

Material.—One specimen (NMNS PM25126) from loc. Iwd-13U; two specimens (NMNS PM 25127) from loc. Iwd-22.

Remarks.—This species is represented by three specimens from the Negishi Formation. The shell is characterized by its small shell size (H＜10 mm), about 30 fine radial threads and two centrally-placed furrows on the exterior surface. The shell characteristics suggest that this specimen resembles *Limatula* (*Limatula*) *vladivostokensis* Scarlato, 1955 and *Limatula* (*Limatula*) *choshiensis* Kuroda and Habe, 1961. However, its specific identification is difficult due to the incompleteness of the material.

Occurrence.—Negishi Fm., locs. Iwd-13U, 22.

Family Gryphaeidae Vyalov, 1936
Subfamily Pycnodonteinae Stenzel, 1959
Genus ***Pycnodonte*** Fischer de Waldheim, 1835
Subgenus ***Phygraea*** Vyalov, 1936

***Pycnodonte* (*Phygraea*)** sp.

Material.—Six specimens (IGUT 12341–12346) from loc. Bat-1.

Remarks.—This unnamed oyster abundantly occurs from the basal conglomerate of the Kobana Formation, as well as some uppermost Lower Miocene strata in central Honshu (e.g., Nenokami Sandstone of Chichibu Basin, Saitama Prefecture and Kurosedani Formation, Toyama Prefecture). The new species will be described elsewhere.

Occurrence: Kobana Fm., locs. Kar-1, Bat-1.

Genus ***Hyotissa*** Stenzel, 1971

Hyotissa? sp.

(Fig. 14A, B)

Material.—Three specimens (NMNS PM25128, 25129) from loc. Iwd-7.

Remarks.—Abundant but poorly preserved oyster specimens were collected from the Ichinokawa Formation. The plicate shell exterior suggests that the species belongs to *Hyotissa* but the chomata diagnostic of the genus is not preserved in the specimens.

Occurrence.—Ichinokawa Fm., loc. Iwd-7.

Family Ostreidae Rafinesque, 1815
Subfamily Crassostreinae Scarlato and Starobogatov, 1979
Genus ***Crassostrea*** Sacco, 1897

Crassostrea gigas (Thunberg, 1793)

(Fig. 14C)

Ostrea gigas Thunberg, 1793, p. 140–141, pl. 6, figs. 1–3.

Crassostrea gigas (Thunberg): Matsubara, 1995, p. 324, figs. 1.23, 4.12 [contains synonymies]; Coan *et al*., 2000, p. 217–218, pl. 37, 2 figs.

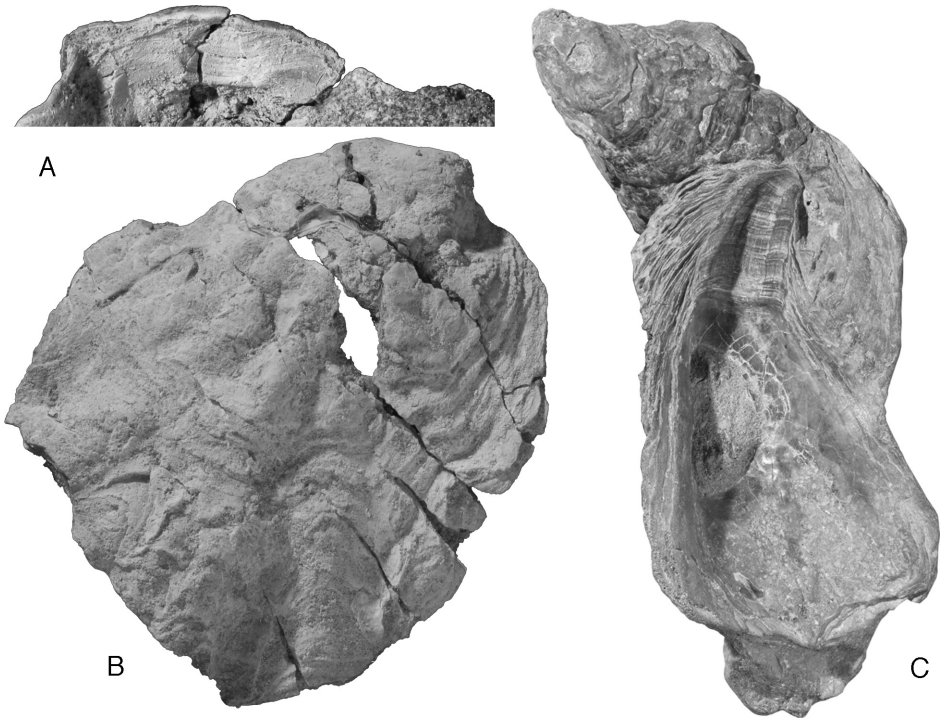


Fig. 14. **A, B**. *Hyotissa*? sp. LV, NMNS PM25128, 71.7+×72.0 mm, loc. Iwd-7, Ichinokawa Fm. [A: hinge (×1.2); B: exterior view (×1)]. **C**. *Crassostrea gigas* (Thunberg). LV, GMNH PI2175, loc. Tom-HN8, Itahana Fm. [interior (×0.6)].

Material.—Three specimens (GMNH PI2175–2177) from loc. Tom-HN8.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is recorded in the upper Lower Miocene to Holocene formations in Japan, and its fossil occurrence was summarized by Matsubara (1995). This species is natively distributed in the intertidal zone of northwestern Pacific from Sakhalin to Pakistan (Coan *et al*., 2000).

Family Dimyidae P. -H. Fischer I, 1886
Genus ***Dimya*** Rouault, 1850

Dimya sp.

Chama sp.: Hayashi *et al*., 2004, table 2.

Material.—One specimen (NSM PM15130) from loc. Iwd-10, one specimen (NMNS PM15131) from loc. Iwd-18; one specimen (NSM PM15132) from loc. Kar-10.

Remarks.—The specimens examined are characterized by their small shell size (L＜20 mm), irregular shell form, thin shell thickness, nearly flat shell convexity, irregular commarginal lamellae on the exterior surface and finely crenulated inner margin. These shell characteristics suggest that they are referable to the left valves of *Dimya*. Their preservation is too poor to allow specific identification.

Occurrence.—Kobana Fm., loc. Kar-4; Negishi Fm., locs. Iwd-9, 10, 18; Oya Fm., loc. Uts-3.

Family Propeamussidae R. T. Abbott, 1954
Genus ***Propeamussium*** de Gregorio, 1884

Propeamussium tateiwai Kanehara, 1936

Propeamussium tateiwai Kanehara, 1936, p. 33–35, pl. 10, figs. 5, 6; Kurihara, 2000, p. 10–11, pl. 4, figs. 18–20 [contains synonymies].

Material.—Six specimens (GMNH PI2033–2038) from loc. Tom-19.

Occurrence: Haratajino Fm., locs. Tom-1, 2, 19, HN2.

Propeamussium fuganjiensis Yamana, 1997

Propeamussium fuganjiensis Yamana, 1997, p. 88, pl. 21, figs. 1a–3, pl. 22, figs. 1–6 [as *Propeamussium fuganjiensis* Omori and Inoue]; Kurihara, 2000, p. 11–12, pl. 4, fig. 22 [contains synonymies]

Material.—One specimen (GMNH PI2039) from loc. Tom-HN2.

Occurrence: Haratajino Fm., loc. Tom-HN2.

Genus ***Parvamusium*** Sacco, 1897

Parvamusium tochigiense (Kanno, 1961) comb. nov.

(Fig. 15B–D)

Cyclopecten tochigiensis Kanno, 1961, p. 115–116, pl. 6, figs. 1–3.
?*Polynemamussium yasudae* Masuda, 1962, p. 156–157, pl. 18, figs. 9a–11.

Material.—One specimen (NMNS PM25133) from Kar-16; two specimens (NMNS PM25134, 25135) from loc. Iwd-13U; one specimen (NMNS PM25136) from loc. Iwd-19; three

specimens from loc. Iwd-22 (NMNS PM25137, 25138).

Remarks.—The shell is small (L, H＜11 mm), slightly convex, and equilateral except for the auricles. The exterior of the right valve is sculptured with distinct commarginal lamellae that are crossed by very faint radial threads. The radial threads are more distinct both on the antero- and postero-ventral margins. The exterior of the left valve is sculptured with fine commarginal lirae in the early growth stage, and later with more than 15 radial rows of scales that are narrower than their interspaces. The interior surface is smooth in small specimens, but in a large specimen with some very weak radial ribs both on the antero- and postero-ventral margins.

These shell characteristics agree well with those of *Cyclopecten tochigiensis*, which was originally described by Kanno (1961) from the Miocene Kobana Formation in the Oto area, Tochigi Prefecture. I here transfer the generic position of this species from *Cyclopecten* to *Parvamussium* because of the presence of interior radial ribs, although the morphologic difference between the two genera appears to be gradational (Hayami and Kase, 1993).

This species closely resembles the Pliocene to Recent *Parvamussium intuscostatum* (Yokoyama, 1920), but is distinguishable only in having more indistinct interior radial ribs. *Polynemamussium yasudae* Masuda, 1962, originally described from the Miocene Oido Formation, Miyagi Prefecture, may be conspecific with this species, but further examination is needed for its confirmation.

Occurrence.—Negishi Fm., locs. Iwd-13U, 15, 19, 22; Kobana Fm., locs. Kar-4, 16.

Stratigraphic and geographic range.—This species was previously reported only from the Miocene Kobana Formation.

Family Pectinidae Rafinesque, 1815
Subfamily Camptonectinae Habe, 1977
Genus ***Delectopecten*** Stewart, 1930

Delectopecten macrocheiricolus Habe, 1951

(Fig. 15A)

Palliolum (*Delectopecten*) *macrocheiricolus* Habe, 1951, p. 80.
Delectopecten vitreus macrocheiricolus (Habe): Hayami, 2000b, p. 907, pl. 41, fig. 49.

Material.—One specimen (NMNS PM25139) from loc. Iwd-22; two specimens (NMNS PM25140) from loc. Tom-45a.

Remarks.—The specimens examined are characterized by their rather small shell size (L＜10 mm), semi-circular shell outline, the posterior auricle merged with disc and no remarkable exterior sculpture except very faint commarginal lines near the ventral margin. This species closely related to the Eocene to Miocene species *Delectopecten peckhami* (Gabb, 1869), but is distinguished in lacking weak commarginal undulations.

Occurrence.—Itahana Fm., loc. Tom-45a; Godo Fm., loc. Iwd-9; Negishi Fm., locs. Iwd-15, 18, 22.

Stratigraphic and geographic range.—This species ranges from the Middle Miocene to Holocene. The specimens from the Negishi Formation represent the oldest fossil record of this species. This species is currently known to occur at depths of 150–1000 m, central and south Japan (Hayami, 2000b).

Delectopecten sp. cf. ***D. peckhami*** (Gabb, 1869)

Delectopecten cf. *peckhami* (Gabb): Kurihara, 1999, fig. 6.20.

Material.—One specimen (IGUT 11837) from loc. Iwd-1.
Occurrence.—Arakawa Fm., loc. Iwd-1, 2.

Subfamily Pectininae Rafinesque, 1815
Tribe Aequipectinini F. Nordsieck, 1969
Genus ***Cryptopecten*** Dall, Bartsch and Rehder, 1938

Cryptopecten yanagawaensis (Nomura and Zinbô, 1936)

(Fig. 21D)

Pecten (*Aequipecten?*) *yanagawaensis* Nomura and Zinbô, 1936b, p. 337, pl. 20, figs. 2a, b.
Cryptopecten yanagawaensis (Nomura and Zinbo): Masuda, 1958a, p. 189, pl. 27, figs. 1–8; Hayami, 1984, p. 113, pl. 8, figs. 6–9; Sato, 1991, p. 70–78, pl. 12, figs. 1–17a, pl. 13, figs. 1–20 [contains synonymies]; Kashiwamura, 1992, pl. 1, figs. 3, 4; Noda *et al*., 1994, fig. 10.1; Ozawa *et al*., 1995, p. 178–180, fig. 3.1–3.4.
Aequipecten yanagawaensis (Nomura and Zinbo): Masuda, 1962, p. 192, pl. 26, fig. 8.

Material.—Three specimens (IGUT 14302) from loc. Kar-1; nine specimens (NMNS PM25159, 25160) from loc. Iwd-7.

Remarks.—*Cryptopecten yanagawaensis* (Nomura and Zinbô, 1936) is characterized by its moderate-sized shell (L<45 mm) and 18–20 flat-topped, regularly developed radial ribs that are almost same in width as the interspaces.

Occurrence.—Kobana Fm., loc. Kar-1; Ichinokawa Fm., loc. Iwd-7.

Stratigraphic and geographic range.—This species is reported in lower Middle Miocene formations in Honshu. Its fossil occurrence was summarized by Sato (1991).

Subfamily Chlamydinae von Teppner, 1922
Tribe Chlamydini von Teppner, 1922
Genus ***Chlamys*** [Röding, 1798]
Subgenus ***Chlamys*** s. s.

Chlamys (***Chlamys***) ***ingeniosa ingeniosa*** (Yokoyama, 1929)

(Fig. 15E–H)

Pecten (*Chlamys*) *hasatus* Sowerby, var. *ingeniosa* Yokoyama, 1929, p. 5, pl. 6, fig. 2.
Chlamys (*Chlamys*) *ingeniosa* (Yokoyama): Masuda, 1962, p. 170, pl. 22, fig. 13.
?*Chlamys ingeniosa* (Yokoyama): Itoigawa *in* Itoigawa *et al*., 1974, p. 64–65, pl. 9, figs. 1a, b.
Chlamys cf. *ingeniosa* (Yokoyama): Ogasawara *et al*., 1989, p. 79, pl. 2, fig. 12.
Chlamys (*Chlamys*) *ingeniosa ingeniosa* (Yokoyama): Amano, 1994, figs. 3.5, 3.8.
Chlamys ingeniosa ingeniosa (Yokoyama): Kurihara and Yanagisawa, 2002, pl. 2, figs. 6, 8, 9; Nomura and Tazaki, 2007, p. 86–88, fig. 4.

Material.—One specimens (IGUT 14309) from loc. Kar-4; five specimens (IGUT 14307, 14310; NMNS PM25141, 25142) from loc. Kar-25; one specimen (IGUT 14306) from loc. Kar-42 (float).

Remarks.—The specimens examined are characterized by their medium shell size (L, H<75 mm) for *Chlamy*s s. s., moderate-sized auricles, ctenolium with 7 or 8 teeth, hinge dentition typical of *Chlamys* s. s. and more than 20 uneven, dichotomous scaly radial ribs and shagreen mi-

crosculpture on the interspaces. The number of radial ribs is difficult to count because of their irregular splitting pattern. These shell characteristics agree well with those of *Chlamys* (*Chlamys*) *ingeniosa ingeniosa* (Yokoyama, 1929).

Chlamys (*Chlamys*) *ingeniosa tanakai* Akiyama, 1958 from the Pliocene Shigarami Formation, Nagano Prefecture, is said to be distinguished from this subspecies by having a smaller apical angle, later splitting radial ribs, stronger intercalated riblets, and a smaller resilial pit on the right valve (Amano, 1994). As suggested by MacNeil (1967, p. 25), the present subspecies may be related to *Chlamys* (*Chlamys*) *islandica behringiana* (Middendorff, 1849), one of the members of the *Chlamys* (*Chlamys*) *islandica* complex of Waller (1991).

Occurrence.—Kobana Fm., locs. Kar-2, 3, 4,17, 25; Shimotezuna Fm., loc. Nkg-1.

Stratigraphic and geographic range.—This subspecies is recorded in Middle Miocene formations of central Honshu. Middle Middle Miocene: Nanao Fm., Ishikawa Pref.; Tenguyama Fm., Toyama Pref. (as comparable species).

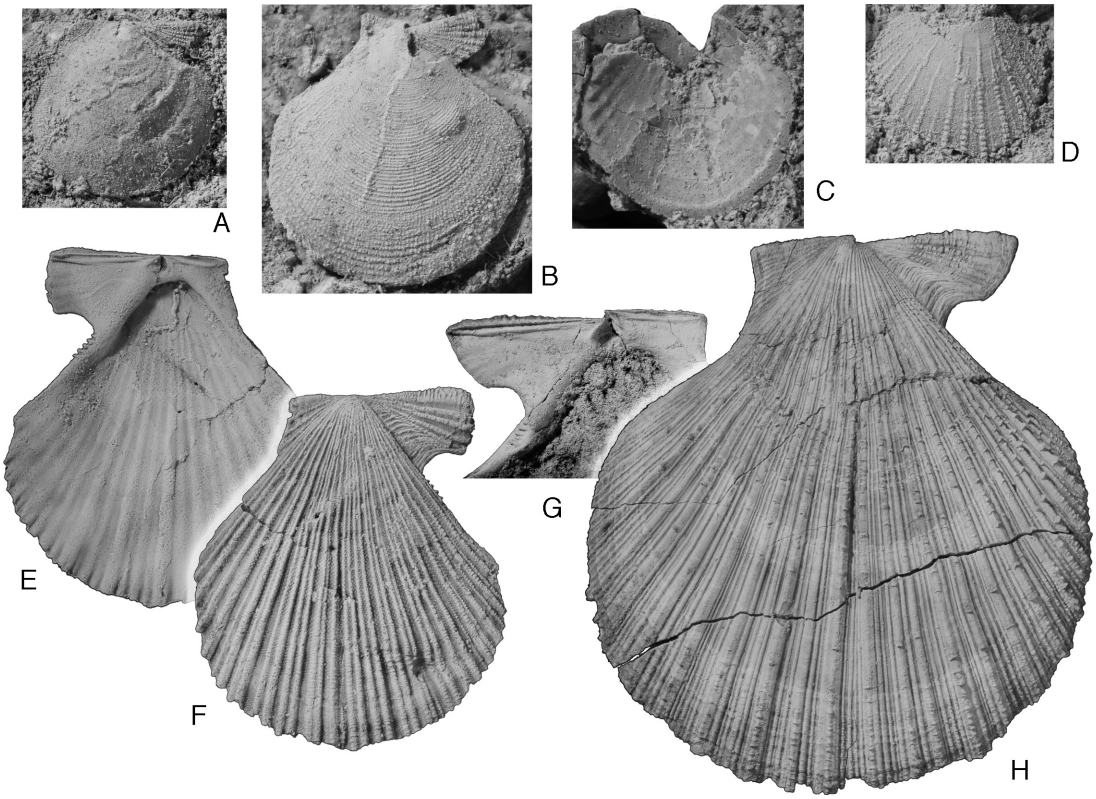


Fig. 15. **A**. *Delectopecten macrocheiricolus* Habe. RV, NMNS PM25139, 6.5×6.3 mm, loc. Iwd-22, Negishi Fm. [exterior (×4)]. **B–D**. *Parvamusium tochigiense* (Kanno) comb. nov. B: RV, NMNS PM25134, 8.4×9.0 mm, loc. Iwd-13U, Negishi Fm. [exterior (×4)]. C: LV, NMNS PM25136, 7.0×7.0+ mm, loc. Iwd-19. [exterior (×4)]. D: LV, NMNS PM25137, 6.0+×5.4 mm, loc. Iwd-22, Negishi Fm. [exterior (×4)]. **E–H**. *Chlamys* (*Chlamys*) *ingeniosa ingeniosa* (Yokoyama). E, F: RV, IGUT 14309, 20.8×24.4 mm, loc. Kar-4, Kobana Fm. [E, interior; F, exterior; (×2)]. G, H: RV, IGUT 14306, 65.4×73.3×14.0 mm, loc. Kar-42, Kobana Fm. [G, interior showing the hinge plate; H, exterior (×1)].

Chlamys (*Chlamys*) *miyatokoensis* (Nomura and Hatai, 1937)

(Fig. 16A–H)

Pecten (*Chlamys*) *miyatokoensis* Nomura and Hatai, 1937, p. 127, pl. 19, figs. 2, 4, pl. 20, fig. 1.
Chlamys miyatokoensis (Nomura and Hatai): Masuda, 1956b, p. 247–249, pl. 35, fig. 1a–9b; Ogasawara and Sato, 1986, p. 16–17, pl. 2, fig. 7.
Chlamys cosibensis (Yokoyama): Ogasawara and Sato, 1986, pl. 1, figs. 1–3, 5–7 [not of Yokoyama, 1911].
Chlamys cf. *otukae* Masuda: Ogasawara and Sato, 1986, pl. 1, figs. 4, 8.
Chlamys sp.: Matsubara, 1996, p. 19–20, pl. 1, figs. 1, 4, 7.

Material.—Eight specimens (IGUT 14349–14351, 14353, 14355, 14356, 14357, 14359) from loc. Bat-3.

Remarks.—The specimens of *Chlamys* from the Ogane Formation in the Bato area show a very wide range of variation in the radial ribbing pattern on the disc. The radial ribbing is regularly to irregularly defined, and are smooth to finely scaled. The primary radial ribs are generally 20 to 25 in number, but some specimens have only several remarkably thick ribs with numerous subordinate riblets. The shell characteristics of the specimens possessing the regularly defined, finely scaled radial ribs agree well with the syntypes of *Chlamys* (*Chlamys*) *miyatokoensis*

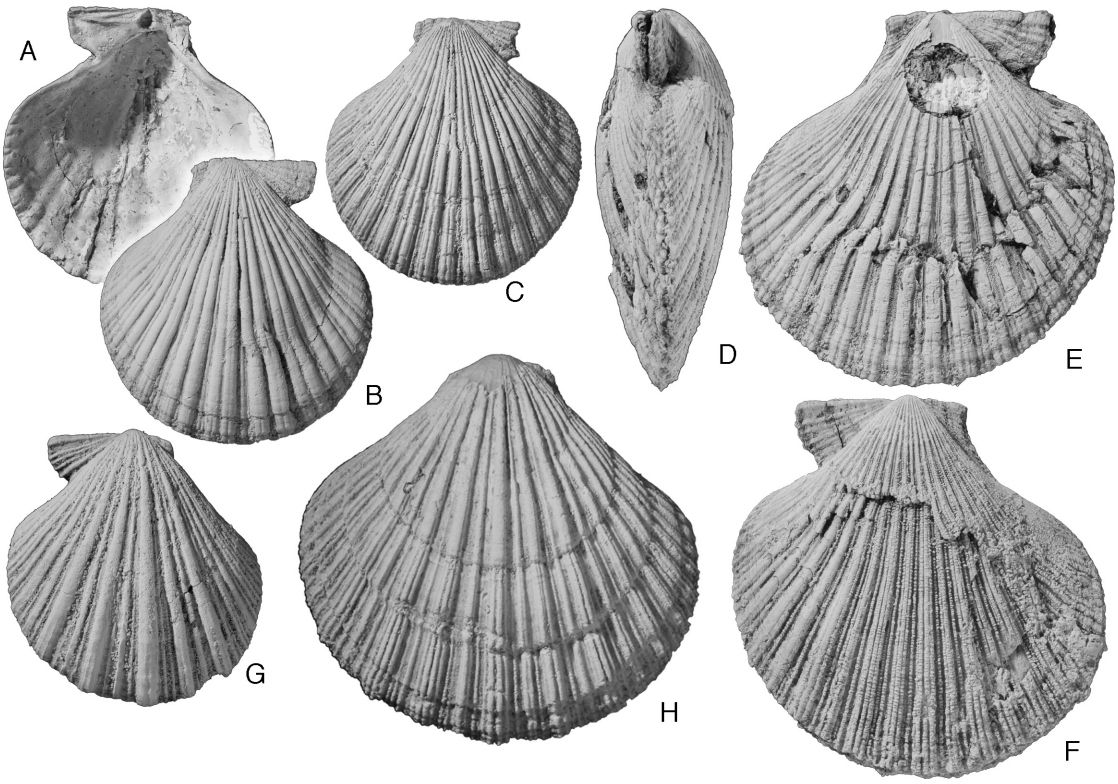


Fig. 16. **A–H**. *Chlamys* (*Chlamys*) *miyatokoensis* (Nomura and Hatai). A, B: RV, IGUT 14357, 50.5×53.6×14.0 mm. [A, interior; B, exterior (×0.7)]. C: RV, IGUT 14356, 47.8×49.6×13.6 mm. [exterior (×0.7)]. D, E, F: CV, IGUT 14355, 49.4×50.4×18.0 (conjoined, slightly deformed) mm. [D, anterior view; E, right view; F, left view (×1)]. G: LV, IGUT 14350, 33.3×36.2×10.0 mm [exterior (×1)]. H: LV, IGUT 14353, 52.2×50.6×15.8 mm [exterior (×1)]. All loc. Bto-3, Ogane Fm.

(Nomura and Hatai, 1937). The specimens from the Ogane Formation indicate that this species shows a much greater intra-specific variation in the exterior sculpture than previously considered. It is noteworthy that the wide variation of the radial ribbing pattern in the specimens examined is comparable with that of *Chlamys* (*Chlamys*) *islandica* (Müller, 1776) from the Pleistocene Setana Formation, Hokkaido, documented by Shikama and Ikeya (1964). This similarity strongly suggests that this species belongs to the *Chlamys* (*Chlamys*) *islandica* complex of Waller (1991).

Some Japanese paleontologists considered that the *C*. (*C*.) *islandica* complex invaded from the North Atlantic through the Arctic into the North Pacific after the opening of the Bering Strait (e.g., Hayami, 1989). Although further investigation is needed, the presence of the *C*. (*C*.) *islandica* complex in the Miocene of Japan suggests that this view is incorrect and that the *C*. (*C*.) *islandica* complex originated in the North Pacific and invaded into the North Atlantic after the opening of the Bering Strait, as suggested by Waller (1991).

Occurrence.—Ogane Fm., loc. Bat-3.

Stratigraphic and geographic range.—Upper Middle Miocene: Utsuno Fm., Miyagi Pref. Ginzan Fm., Yamagata Pref. Lower Upper Miocene: Otsutsumi Fm., Miyagi Pref.

Subgenus ***Leochlamys*** MacNeil, 1967

Chlamys (***Leochlamys***) sp. cf. ***C***. (***L***.) ***arakawai*** (Nomura, 1935)

(Fig. 22B)

Compare.—

Pecten (*Pecten*) *arakawai* Nomura, 1935b, p. 41, pl. 4, figs. 1, 2.

Chlamys arakawai (Nomura): Sato, 1991, p. 30–38, pl. 1, figs. 1–9b, pl. 2, figs. 1–9b, pl. 3, figs. 1–6 [contains synonymies].

Material.—Two specimens (IGUT 14304) from loc. Kar-1; one specimen (NMNS PM25143) from loc. Iwd-7.

Remarks.—The specimens examined are all incomplete. The specimen illustrated is a small right valve with 27 radial ribs.

Occurrence.—Kobana Fm., loc. Kar-1; Ichinokawa Fm., loc. Iwd-7.

Stratigraphic and geographic range.—*Chlamys* (*Leochlamys*) *arakawai* Nomura, 1935 is reported in lower Middle Miocene formations in Honshu and Hokkaido. Its fossil occurrence was summarized by Sato (1991).

Subgenus ***Nomurachlamys*** Kurihara and Matsubara* subgen. nov.

Type species.—*Pecten kaneharai* Yokoyama, 1926a. Lower Upper Miocene of Honshu, Japan.

Diagnosis.—Chlamydini with small- to large-sized, bi-convex shell; both valves sculptured by 20–28, regular, flat-topped, bi- or trifurcated radial ribs separated by interspaces each having a single interstitial riblet; shagreen microsculpture may present in the grooves on ribs and interspaces; inner disc margin distinctly carinated; dorsal margins almost straight, retaining longer than half of shell length throughout shell growth; anterior auricle larger than posterior auricle, on RV with deep byssal notch and five functional ctenolium; hinge typical of *Chlamys*, but RV resilial and dorsal teeth prominent.

* Takashi Matsubara (Museum of Nature and Human Activities, Hyogo)

Remarks.—*Nomurachlamys* subgen. nov. resembles the subgenus *Chlamys* [Röding, 1798] (type species: "*Pecten islandicus* Linn." [=*Pecten islandicus* Müller, 1776] by subsequent designation) in many respects. However, *Nomurachlamys* subgen. nov. differs from *Chlamys* s.s. in having regular, bi- or trifurcated radial ribs with a single interstitial riblet in both valves, radially carinated disc margin, and the prominent resilial and dorsal hinge teeth. The new subgenus has a superficial resemblance to the genus *Mimachlamys* Iredale, 1929 (type species: *Pecten asperrimus* Lamarck, 1819 by original designation; tribe Mimachlamydini), as it shares with that genus the regular radial ribs and a deep byssal notch. Masuda (1962) referred some constituents of *Nomurachlamys* subgen. nov. to *Mimachlamys.* However, the new subgenus differs from *Mimachlamys* in having flat-topped primary radial ribs and the shagreen microsculpture, instead of rounded primary radial ribs and "herringbone" and "feather" type microsculpture. The shagreen microsculpture is one of the diagnostic characters of the tribe Chlamydini (Waller, 1993; Beu and Darragh, 2001). The new subgenus is also similar to the Miocene–Pliocene genus *Phialopecten* Marwick, 1928 (type species: *Pecten triphooki* Zittel, 1864, by original designation; tribe Palliolini, see Beu, 1995) in New Zealand. However, *Phialopecten* is distinguished from *Nomurapecten* subgen. nov. by having a shallower byssal notch and a larger, posteriorly oblique posterior auricle, and in lacking the shagreen microsculpture.

Nomurachlamys subgen. nov. includes the following species in addition to the type species: *Chlamys* (*Chlamys*) *ishidae* Masuda, 1962 from the uppermost Lower Miocene of Honshu; *Pecten* (*Chlamys*) *meisensis* Makiyama, 1926 from the lower Middle to upper Middle Miocene of Honshu and Korean Peninsula. Besides, *Pecten miurensis* Yokoyama, 1920 from the upper Upper Miocene to Lower Pliocene of Honshu, *Pecten akitanus* Yokoyama, 1926 from the lower Middle Miocene of Honshu, and *Pecten nisataiensis* Otuka, 1934 from the uppermost Lower Miocene of Honshu may be members of the new subgenus, but their subgeneric assignment are suspended herein because its external microsculpture and precise interior characters are not fully understood.

Etymology.—The new subgenus is named in honor of the late Dr. Sitihei Nomura (1892–1946), who greatly contributed to our knowledge of the systematics of Neogene and Recent molluscs in Japan, combined with the pectinid genus name *Chlamys*. The gender is feminine.

Chlamys* (*Nomurachlamys*) *kaneharai (Yokoyama, 1926)

(Fig. 17A–E)

Pecten kaneharai Yokoyama, 1926a, p. 135–136, pl. 18, fig. 1, pl. 19, figs. 1, 2, 5–7; Yokoyama, 1931, p. 203, pl. 13.

Pecten (*Chlamys*) *kaneharai* Yokoyama: Nomura and Hatai, 1936, p. 119, pl. 13, figs. 3, 4; Nomura and Hatai, 1937, p. 127, pl. 18, figs. 1, 2; Nomura and Ônisi, 1940, p. 181, pl. 18, fig. 8.

Chlamys kaneharai (Yokoyama): Masuda, 1956a, p. 176, pl. 28, figs. 1–7; Iwasaki, 1970, p. 396–397, pl. 6, figs. 7, 8; Hatai *et al*., 1974, pl. 4, figs. 3, 4; Narita *et al*., 2001, fig. 3.13.

Chlamys (*Mimachlamys*) *kaneharai* (Yokoyama): Masuda, 1962, p. 187, pl. 20, fig. 7, pl. 22, figs. 8–10, pl. 26, figs. 11, 12.

Not *Chlamys* (*Mimachlamys*) *kaneharai* (Yokoyama): Shikama, 1973, p. 200, pl. 17, fig. 5 [=*Chlamys miurensis* (Yokoyama, 1920)].

Material.—Five specimens (GMNH PI2178–2182) from loc. Tom-HN8; one specimen (NMNS PM25144) from loc. Tom-17a.

Remarks.—The shell is large (L, H<120 mm), as long as high or slightly longer than high, moderately inflated and nearly equilateral except for the auricles. The disc sculpture consists of

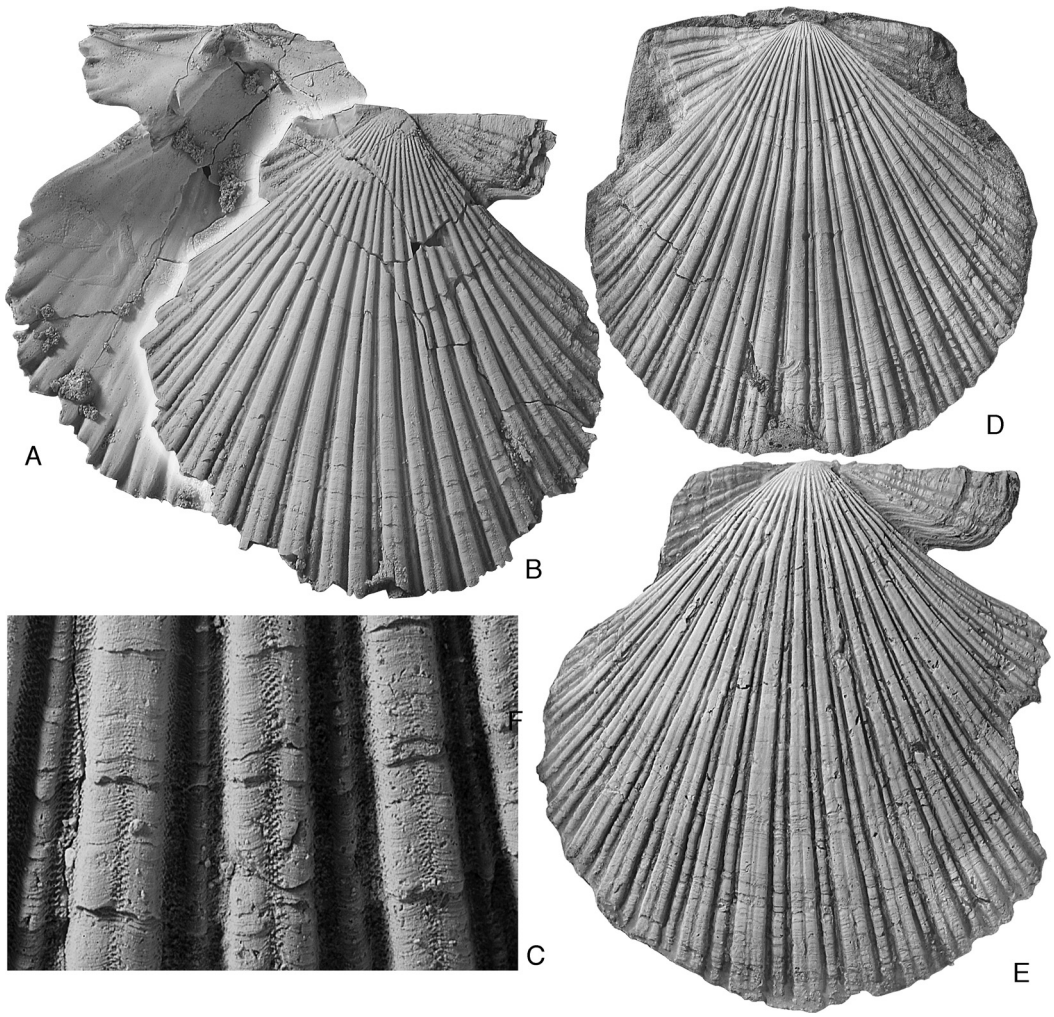


Fig. 17. **A–D**. *Chlamys* (*Nomurachlamys*) *kaneharai* (Yokoyama). A–C: RV, NMNS PM25144, 61.0×65.4×12.4 mm, loc. Tom-17a, Itahana Fm. [A, exterior (×1); B, interior (×1); C, part of the disc showing the shagreen microsculpture (×4.5)]. D: LV, GMNH PI2179, 118.0×116.6+mm, loc. Tom-HN8, Itahana Fm. [exterior (×0.5)]. E: RV, GMNH PI2178, 136.0+×145.4 mm. loc. Tom-HN8, Itahana Fm. [exterior (×0.5)].

about 20, even radial ribs divided by interspaces that are equal to or slightly wider than the ribs. The radial ribs are smooth in immature stage, but are subdivided into two or three, scaly secondary riblets in mature stage. The shagreen microsculpture is developed only on the interspaces. The Itahana specimens examined fall within the variation of *Chlamys* (*Nomurachlamys*) *kaneharai* (Yokoyama, 1926) described by Iwasaki (1970) from the Kubota Formation, Fukushima Prefecture.

The Late Miocene to Pliocene *Chlamys miurensis* (Yokoyama, 1920) resembles this species, but differs from this species in having more number of radial ribs (22–25) and two or three secondary riblets with scales in each interspace.

Occurrence.—Itahana Fm., locs. Tom-17a, 45a, HN8.

Stratigraphic and geographic range.—This species is reported in upper Middle to lower Upper Miocene formations in Honshu. Upper Middle Miocene: Aoki Fm., Nagano Pref. Lower Upper Miocene: Otsutsumi and Nanakita Fms., Miyagi Pref.; Kubota Fm., Fukushima Pref.; Kanomatazawa Fm., Tochigi Pref.

Chlamys* (*Nomurachlamys*) *meisensis (Makiyama, 1926)

(Fig. 18A–F)

Pecten (*Chlamys*) *meisensis* Makiyama, 1926, p. 156, pl. 13, fig. 4.
Chlamys meisensis Makiyama: Makiyama, 1936, p. 206.

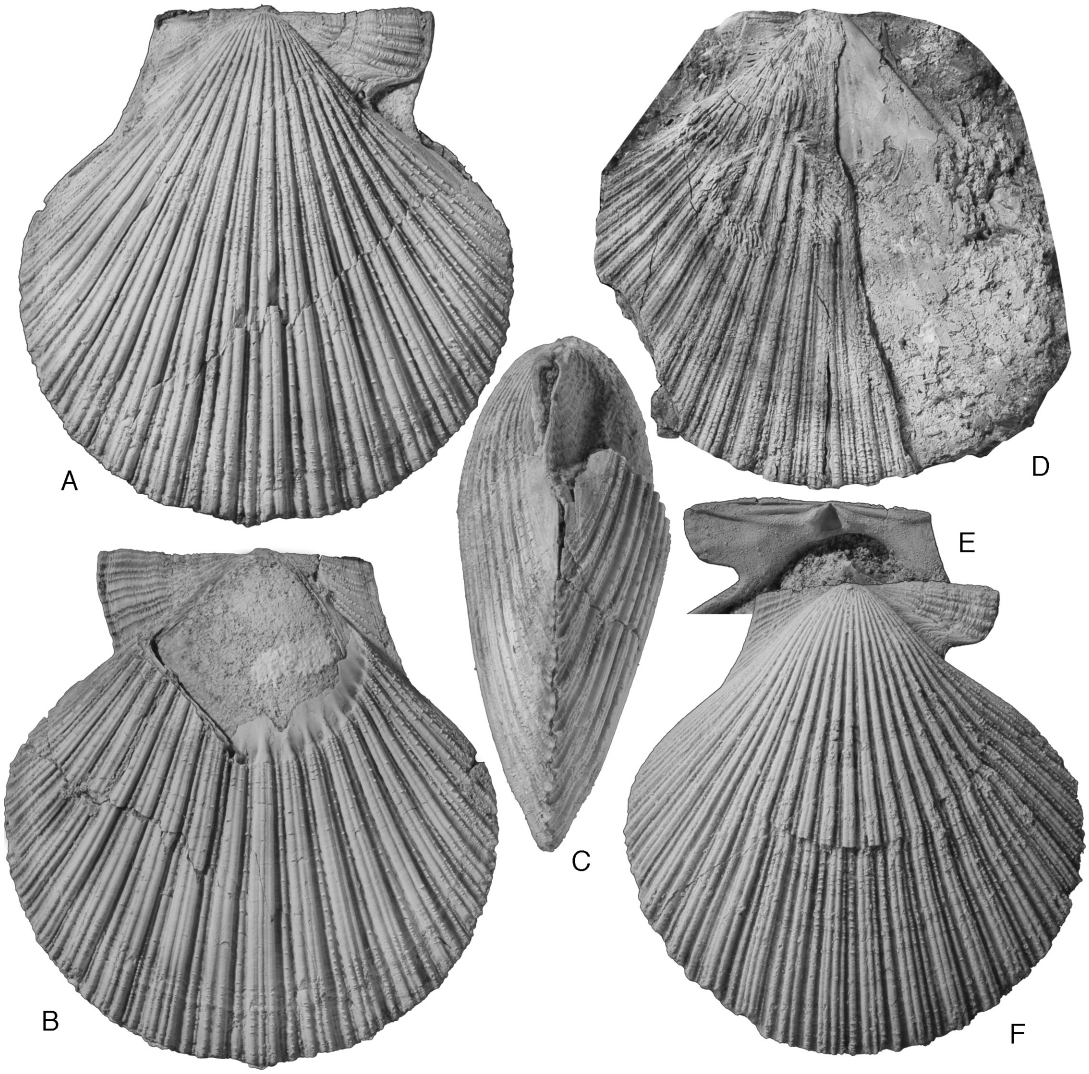


Fig. 18. **A–F**. *Chlamys* (*Nomurachlamys*) *meisensis* (Makiyama). A–C: CV, IGUT 14391, 65.0×70.4×22.0+ (×2) mm, loc. Uts-1, Oya Fm. [A, right view; B, left view; C, anterior view (×1)]. D: LV, NMNS PM25145, 56.0+×60.9 mm, loc. Iwd-10, Negishi Fm. [exterior (×1)]. E, F; RV, NMNS PM25147, 61.0×62.8×13.0 mm, loc. Uts-1 [E, hinge; F, exterior (×1)].

Chlamys (*Mimachlamys*) *meisensis* (Makiyama): Masuda, 1962, p. 187–188, pl. 23, fig. 2.
Chlamys meisensis Makiyama: Ogasawara *et al*., 1989, p. 77–79, pl. 1, figs. 9–11, pl. 3, figs. 2, 3, 5, 6; Kurihara and Yanagisawa, 2002, pl. 1, figs. 3, 6.
Chlamys hataii Masuda and Akutsu, 1956, p. 130–131, pl. 20, figs. 1a–6b; Hayashi *et al*., 2004, table 2.

Material.—Four specimens (NMNS PM25145, 25146) from loc. Iwd-10; 24 specimens (IGUT 14391–14393; NSM PM25147, 25148) from loc. Uts-1.

Remarks.—The specimens examined are characterized by the moderate shell size (L, H<75 mm), 20 to 23 regularly-dichotomous radial ribs with scales on the disc exterior, the strongly developed resilial and dorsal teeth, and the internal carinae at the shell margin. The shagreen microsculpture is recognized on the shallow median furrows of the primary radial ribs in some specimens. These shell characteristics agree well with those of the holotype and topotypes of *Chlamys* (*Nomurachlamys*) *meisensis* (Makiyama, 1926).

Chlamys hataii Masuda and Akutsu, 1956 described from the Oya Formation, Tochigi Prefecture is regarded herein as a junior synonym of this species for the first time. *C. hataii* was said to differ from *C. meisensis* in its smaller shell size and less number of radial ribs in the original description. However, newly obtained topotype specimens of *C. hataii* reveal that these two species are indistinguishable each other by the shell size and number of radial ribs. This species is closely related to the Upper Miocene *Chlamys* (*Nomurachlamys*) *kaneharai* (Yokoyama, 1926), but is distinguished in its smaller shell size and more number of radial ribs on the disc. The similar shell morphology and the stratigraphic relationship suggest that this species is a possible ancestor of *C.* (*N.*) *kaneharai*.

Occurrence.—Negishi Fm., loc. Iwd-10; Oya Fm., locs. Uts-1, 2a, 2b, 4; Shimotezuna Fm., loc. Nkg-1.

Stratigraphic and geographic range.—This species is recorded in lower Middle to upper Middle Miocene strata in Honshu. Lower Middle Miocene: Tenguyama Fm., Toyama Pref.; Lower Banko Fm., North Korea.

Genus ***Semipallium*** Jousseaume *in* Lamy, 1928

Semipallium crassivenium (Yokoyama, 1929) comb. nov.

(Fig. 19A–E)

Pecten (*Chlamys*) *crassivenius* Yokoyama, 1929, p. 6, pl. 6, fig. 1; Nomura, 1940, p. 19, pl. 2, figs. 13a, b.
Chlamys crassivenia (Yokoyama): Otuka, 1935, p. 886, pl. 55, figs. 137, 139, 141.
Gloripallium crassivenium (Yokoyama): Hirayama, 1954, p. 30–31, pl.3, figs. 11, 12, 18; Masuda, 1958b, p. 224–227, pl. 32, figs. 1a–3d; Yamana, 1979, p. 6–7, pl. 2, figs. 2a–7; O'Hara and Nemoto, 1988, p. 489, pl. 1, fig. 2; Majima, 1989, fig. 12.6; Masuda and Yoshida, 1991, p. 5, pl. 4, fig. 14; Yamana, 1997, p. 82, pl. 18, figs. 1a–7.
Pecten (*Swiftopecten*) *nanakitaensis* Nakamura, 1940, p. 37–38, text-fig. 1.
Cryptopecten oyamadaensis Hirayama, 1954, p. 54, pl. 3, fig. 3.

Material.—Two specimens (GMNH PI2060, 2061) from loc. Tom-HN7; three specimens (IGUT 14317, 14319, 14320) from loc. Kar-40; three specimens (NMNS PM25149, 25150) from loc. Iwd-13U; four specimens (NMNS PM25151–25153) from loc. Iwd-41.

Remarks.—The shell is moderate size (H<70 mm) and higher than long. The disc exterior is sculptured with nine or ten radial ribs that are slightly broader than or the same as wide with the interspaces. There are several riblets with imbricated scales on each radial rib and interspace. The total number of scaly riblets is more than 80 on the shell margin in mature stage.

Semipallium crassivenium (Yokoyama, 1929) is easily distinguished from other Miocene pec-

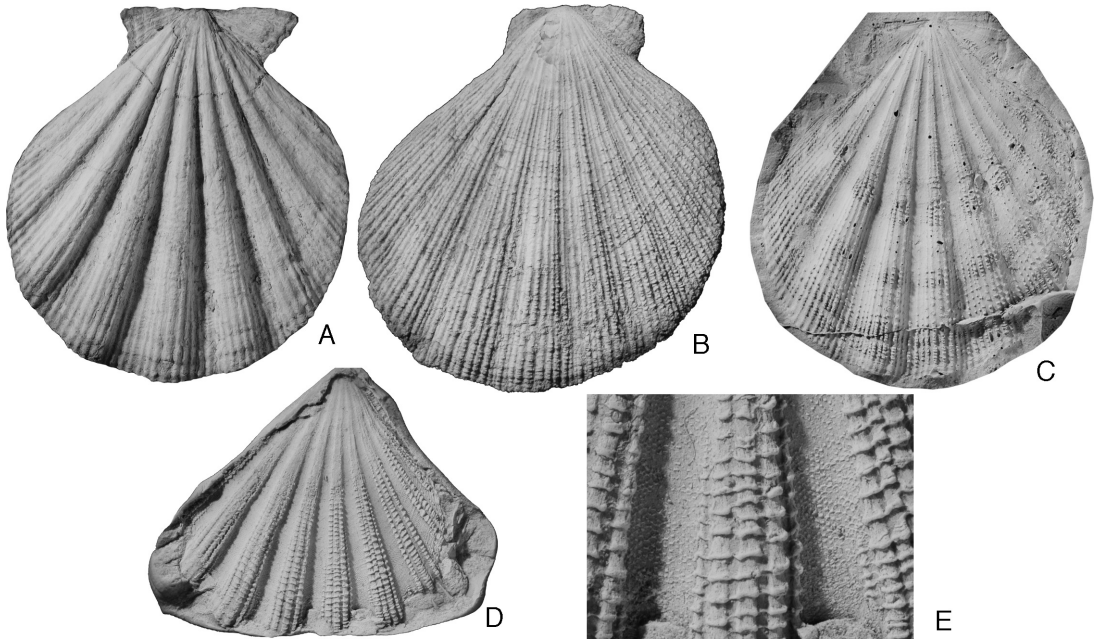


Fig. 19. **A–E**. *Semipallium crassivenium* (Yokoyama) comb. nov. A: RV, GMNH PI2060, loc. Tom-HN7, Haraichi Fm. [exterior (×0.6)]. B: RV, NMNS PM25149, 48.3×51.0 mm, loc. Iwd-13U, Negishi Fm. [exterior (×1)]. C: RV, NSM PM25151, 58.0×65.3 mm, loc. Iwd-41, Shogunzawa Fm., ×1 [exterior rubber cast (×0.7)]. D, E: RV?, NMNS PM25152, 35.7+×34.4+ mm, loc. Iwd-41, Shogunzawa Fm. [D, exterior rubber cast (×1); E, part of disc showing the shagreen microsculpture (×3.5)].

tinids by its characteristic exterior sculpture. This species has been assigned to the genus *Gloripallium* Iredale, 1939 (type species: *Ostrea pallium* Linnaeus, 1758 by original designation) since Hirayama (1954). However, the distinct shagreen microsculpture on the interspaces of radial ornaments suggests that this species is transferred to the genus *Semipallium* Jousseaume in Lamy, 1928 (type species: *Pecten tigris* Lamarck, 1819 by original designation).

Occurrence.—Haraichi Fm., loc. Tom-7; Kobana Fm., locs. Kar-18, 20, 21, 22, 9, 36, 24, 40, 41; Ogane Fm, locs. Kar-38, 5, 26, 6, 27; Godo Fm., loc. Iwd-13L; Negishi Fm., loc. Iwd-13U; Shogunzawa Fm., loc. Iwd-41.

Stratigraphic and geographic range.—The occurrence of this species is restricted to middle Middle and upper Middle Miocene formations, except for that from the Tottori Group (Yamana, 1979, 1997), which may be down to the lower Middle Miocene. O'Hara and Nemoto (1988) reported this species from the Pliocene Futatsunuma Sand of the Tomioka Formation [=Dainenji Formation], Fukushima Prefecture. However, this is likely to have been derived from the underlying Miocene strata because the bed commonly contains a number of reworked fossils. ?Lower Middle Miocene: Tottori Gr. Middle Middle Miocene: Suzukamo Fm., Iwate Pref.; Matsuba Fm., Akita Pref.; Nanao Fm., Ishikawa Pref.

Genus *Nanaochlamys* Hatai and Masuda, 1953

Nanaochlamys notoensis notoensis (Yokoyama, 1929)

(Fig. 20A, B)

Pecten notoensis Yokoyama, 1929, p. 4, pl. 3, figs. 1–4, pl. 4, figs. 1, 2, pl. 5, fig. 1.
Nanaochlamys notoensis (Yokoyama): Sato, 1991, p. 61–69, pl. 9, figs. 1–11, pl. 10, figs. 1–8, pl. 11, figs. 1, 2 [contains synonymies]; Hayashida and Tanabe, 2006, figs. 2A–M.
Nanaochlamys notoensis notoensis (Yokoyama): Hayashi *et al*., 2004, table 2.

Material.—Two specimens (NMNS PM25154, 25155) from loc. Iwd-7.

Remarks.—The shell is moderate in size (H<75 mm), equilateral except for the auricles, and inequivalve. The disc of right valve is sculptured by six primary radial ribs that bifurcate at the shell height of about 15 mm. The secondary bifurcation occurs at the shell height of about 20 mm. The primary intercalary ribs appear at the shell height of about 30 mm. The disc of left valve is nearly flat in immature stage, and is sculptured by five radial ribs, lateral two of which bifurcates on the flat platform. The bifurcation of the other three radial ribs is unknown due to the poor preservation.

Nanaochlamys notoensis notoensis (Yokoyama, 1929) differs from its chronologically younger subspecies, *Nanaochlamys notoensis otutumiensis* (Nomura and Hatai, 1937) in its smaller shell size, stout primary radial ribs, and in the presence of the intercalary riblets between the primary ribs on right valve.

Occurrence.—Ichinokawa Fm., locs. Iwd-5, 7; Oya Fm., loc. Uts-1.

Stratigraphic and geographic range.—This subspecies is reported in lower Middle Miocene formations in Honshu and Hokkaido. Its fossil occurrence was summarized by Sato (1991).

Nanaochlamys sp. cf. *N. notoensis otutumiensis* (Nomura and Hatai, 1937)

Nanaochlamys cf. *otutumiensis* Nomura and Hatai: Kurihara and Yanagisawa, 2002, pl. 2, fig. 7.

Material.—One specimen (IGUT 14387) from loc. Nkg-1.

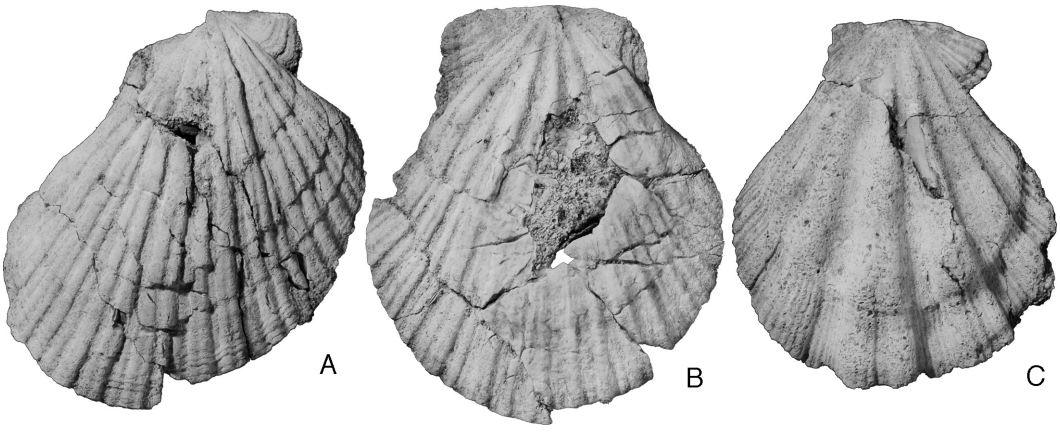


Fig. 20. **A, B**. *Nanaochlamys notoensis notoensis* (Yokoyama). A: RV, NMNS PM25154, 69.0×75.0×15.2 mm, loc. Iwd-7, Ichinokawa Fm. [exterior, strongly deformed (×0.7)]. B: LV, NMNS PM25155, 58.5×68.0×12.0 mm, loc. Iwd-7, Ichinokawa Fm. [exterior, slightly deformed (×0.8)]. **C**: *Nanaochlamys* sp. RV, IGUT 14318, 51.0×58.3×14.0 mm, loc. Kar-4, Kobana Fm. [exterior (×0.8)].

Occurrence.—Shimotezuna Fm., loc. Nkg-1.

Nanaochlamys sp.

(Fig. 20C)

Nanaochlamys notoensis otutumiensis (Nomura and Hatai): Masuda, 1960, pl. 39, figs. 6, 7 [not of Nomura and Hatai, 1937].

Nanaochlamys sp.: Kurihara and Yanagisawa, 2002, pl. 2, fig. 10.

Material.—One specimen (NMNS PM25156) from Kar-2; one specimen (IGUT 14318) from Kar-4; one specimen (NMNS PM25157) from Iwd-15.

Remarks.—This unnamed species is conspecific with the specimen illustrated by Masuda (1960, pl. 39, figs. 6, 7) as *Nanaochlamys notoensis otutumiensis* from the Suenomatsuyama Formation, Iwate Prefecture. Although Masuda (1960) referred the Suenomatsuyama specimens with *N. notoensis otutumiensis*, the specimens differ from those of the subspecies in having finer secondary riblets and shallower median groove of initial ribs as stated by Matsubara (1996). Although the Suenomatsuyama and present specimens may represent a new taxon, additional materials are necessary to clarify their intraspecific variation.

Occurrence.—Kobana Fm., loc. Kar-4; Negishi Fm., loc. Iwd-15; Shimotezuna Fm., loc. Nkg-1.

Tribe Fortipectinini Masuda, 1963

Genus ***Mizuhopecten*** Masuda, 1963

Mizuhopecten paraplebejus (Nomura and Hatai, 1936)

(Fig. 21B, C)

Pecten (*Patinopecten*) *paraplebejus* Nomura and Hatai, 1936, p. 119–121, pl. 13, figs. 6, 7, pl. 16, figs. 6, 7; Iwasaki, 1970, p. 397–399, pl. 5, fig. 1, pl. 6, figs. 3, 4.

Patinopecten paraplebejus (Nomura and Hatai): Masuda, 1959, p. 2–3, pl. 1, figs. 1–6.

Patinopecten (*Patinopecten*) *paraplebejus* (Nomura and Hatai): Masuda, 1962, p. 208–209.

Mizuhopecten paraplebejus (Nomura and Hatai): Matsubara, 1996, p. 21–24, pl. 1, figs. 6, 9, 10, pl. 2, fig. 1 [contains synymies]: Kurihara and Yanagisawa, 2002, pl. 1, figs. 1, 2, 4, 5, 8.

Material.—Two specimens (IGUT 14348, 14352) from loc. Bat-3.

Remarks.—The specimens examined are characterized by the very large shell size (L, H$<$150 mm), moderately thick shell, 20 to 23 radial ribs that become obsolete toward the ventral margin on the disc. According to Iwasaki (1970), the radial rib ranges from 16 to 23 in number in the specimens from the Kubota Formation, Fukushima Prefecture. *Mizuhopecten paraplebejus* (Nomura and Hatai, 1936) closely resembles the Pleistocene to Holocene *Mizuhopecten yessoensis* (Jay, 1857) in the general shell characteristics, but the latter differs from the former in having a thinner shell and more distinctly defined radial ribs.

Occurrence.—Ogane Fm., locs. Kar-14, Bat-3; Shimotezuna Fm., loc. Nkg-1.

Stratigraphic and geographic range.—This species is reported in the upper Middle and lower Middle Miocene formations of Honshu. Upper Middle Miocene: Ginzan Fm., Yamagata Pref. Lower Upper Miocene: Shitazaki Fm., Aomori Pref.; Nanakita Fm., Miyagi Pref.; Kubota Fm., Fukushima Pref.; Kanomatazawa Fm., Tochigi Pref.

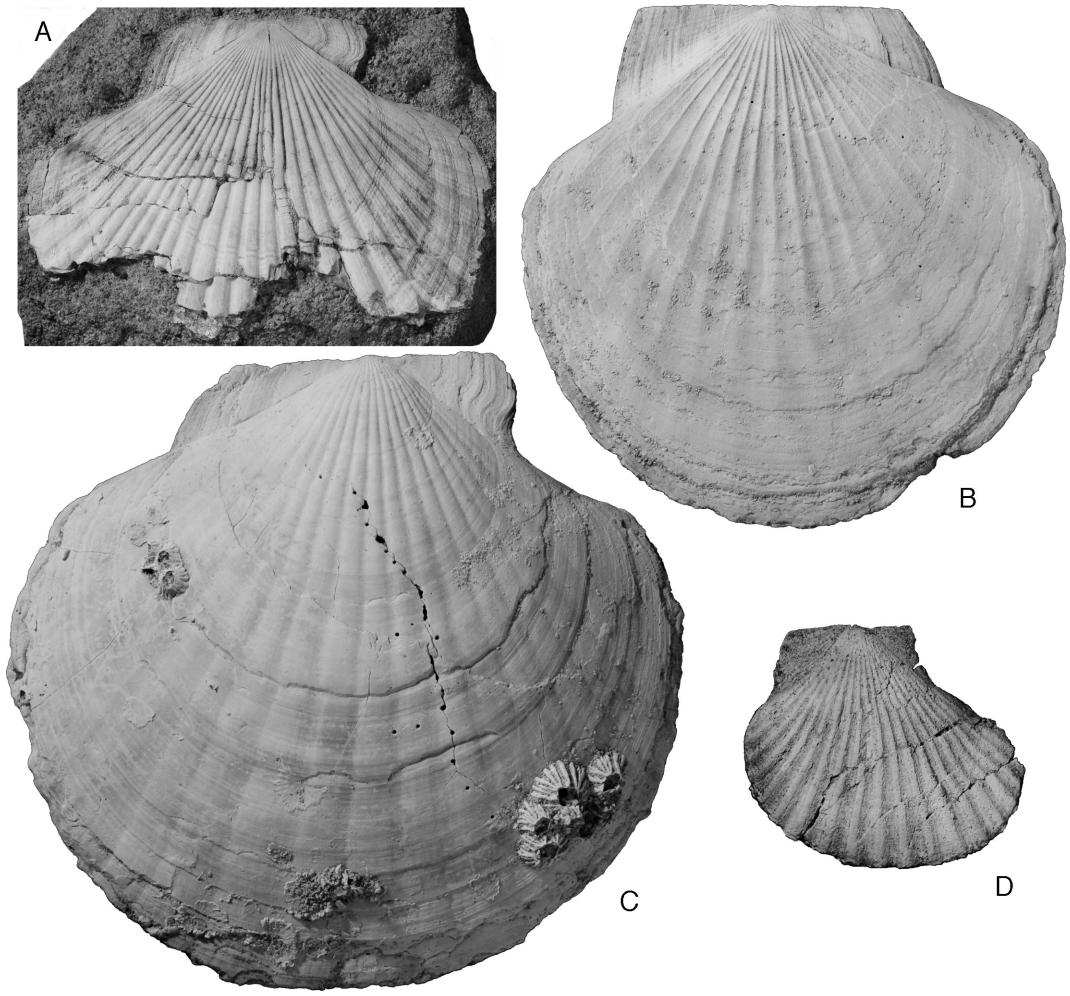


Fig. 21. **A**. *Kotorapecten kagamianus* (Yokoyama). RV, NMNS PM25158, 125+×85+ mm, loc. Uts-1, Oya Fm. [exterior (×0.5)]. **B, C**. *Mizuhopecten paraplebejus* (Nomura and Hatai). B: LV, IGUT 14352, 111.7×116.4×9.0 mm, loc. Bat-3, Ogane Fm. [exterior (×0.5)]. C: RV, IGUT 14348, 148.2×139.0×24.0 mm, loc. Bat-3, Ogane Fm. [exterior (×0.5)]. **D**. *Cryptopecten yanagawaensis* (Nomura and Zinbô). LV, NMNS PM25159, 37.3×33.0×7.8 mm, loc. Iwd-7, Ichinokawa Fm. [exterior, strongly deformed (×1)].

Genus ***Kotorapecten*** Masuda, 1962

Kotorapecten kagamianus (Yokoyama, 1923)

(Fig. 21A)

Pecten kagamianus Yokoyama, 1923b, p. 8, pl. 1, figs. 1a, b.

Kotorapecten kagamianus (Yokoyama): Sato, 1991, p. 96–106, pl. 32, figs. 1–8, pl. 33, figs. 1–7 [contains synonymies]; Kurihara and Yanagisawa, 2002, pl. 1, fig. 9; Hayashi *et al.,* 2004, table 2.

Material.—Two specimens (IGUT 14394; NMNS PM25158) from Uts-1.

Remarks.—The specimens assigned here to *Kotorapecten kagamianus* (Yokoyama, 1923) are

characterized by their large shell size (L<125 mm), weak convexity, and rounded primary radial ribs and numerous secondary radial threads on the disc exterior. The number of primary radial ribs ranges from 17 to 30 in the Oya specimens, and is 24 in the Shimotezuna specimens.

Occurrence.—Oya Fm., locs. Uts-1, 2a, 4; Shimotezuna Fm., loc. Nkg-1.

Stratigraphic and geographic range.—This species is known to occur in lower Middle to upper Middle Miocene strata of Honshu and Hokkaido (see Sato, 1991).

Tribe uncertain

Remarks.—The amusioid pectinid genera *Nipponopecten* Masuda, 1962 (type species: *Pecten akihoensis* Matsumoto, 1930 by original designation) and *Miyagipecten* Masuda, 1952 (type species: *Miyagipecten matsumoriensis* Masuda, 1952) cannot be easily referred to any known tribes. I tentatively described these genera under a tribe uncertain.

Genus ***Nipponopecten*** Masuda, 1962

Nipponopecten sp. cf. ***N. akihoensis*** (Matsumoto, 1930)

(Fig. 22C)

Nipponopecten cf. *akihoensis* (Matsumoto): Kurihara and Yanagisawa, 2002, pl. 2, fig. 5.

Material.—One specimen (IGUT 14308) from loc. Bat-2.

Remarks.—This species is represented by fragmental specimens from the Kobana and Shimotezuna Formations. It is likely to be referable to *Nipponopecten akihoensis* (Matsumoto, 1930) in its large shell size and many, very weak radial ribs divided by narrow and shallow interspaces.

Occurrence.—Kobana Fm., loc. Bat-1; Shimotezuna Fm., loc. Nkg-1.

Nipponopecten protomollitus (Nomura, 1935)

(Fig. 22A)

Pecten (*Pecten*) *protomollitus* Nomura, 1935b, p. 41, pl. 6, fig. 3.
Placopecten protomollitus (Nomura): Sato, 1991, pl. 31, figs. 3a, b; Kaneko and Goto, 1997, p. 9, pl. 5, figs. 1, 2.
Nipponopecten protomollitus (Nomura): Ozawa *et al*., 1996, p. 6–8, pl. 1, figs. 1–6 [contains synonymies]; Hayashi *et al*., 2004, table 2.
Placopecten akihoensis (Matsumoto): Kashiwamura, 1992, pl. 1, figs. 1, 2 [not of Matsumoto, 1930].

Material.—Ten specimens (IGUT 14305; NMNS PM25161) from loc. Kar-1.

Remarks.—This specimens referred here to *Nipponopecten protomollitus* (Nomura, 1935) is characterized by their moderate shell size (L, H<55 mm), thin shell, weak convexity, and 42–53 radial threads on the disc exterior. The radial threads on the disc of the right valve are smooth, whereas those on the disc of the left valve bear fine scales.

Occurrence.—Kobana Fm., locs. Kar-1, Bat-1; Oya Fm., loc. Uts-3.

Stratigraphic and geographic range.—This species is recorded in lower Middle Miocene strata in Honshu (see Ozawa *et al*., 1996).

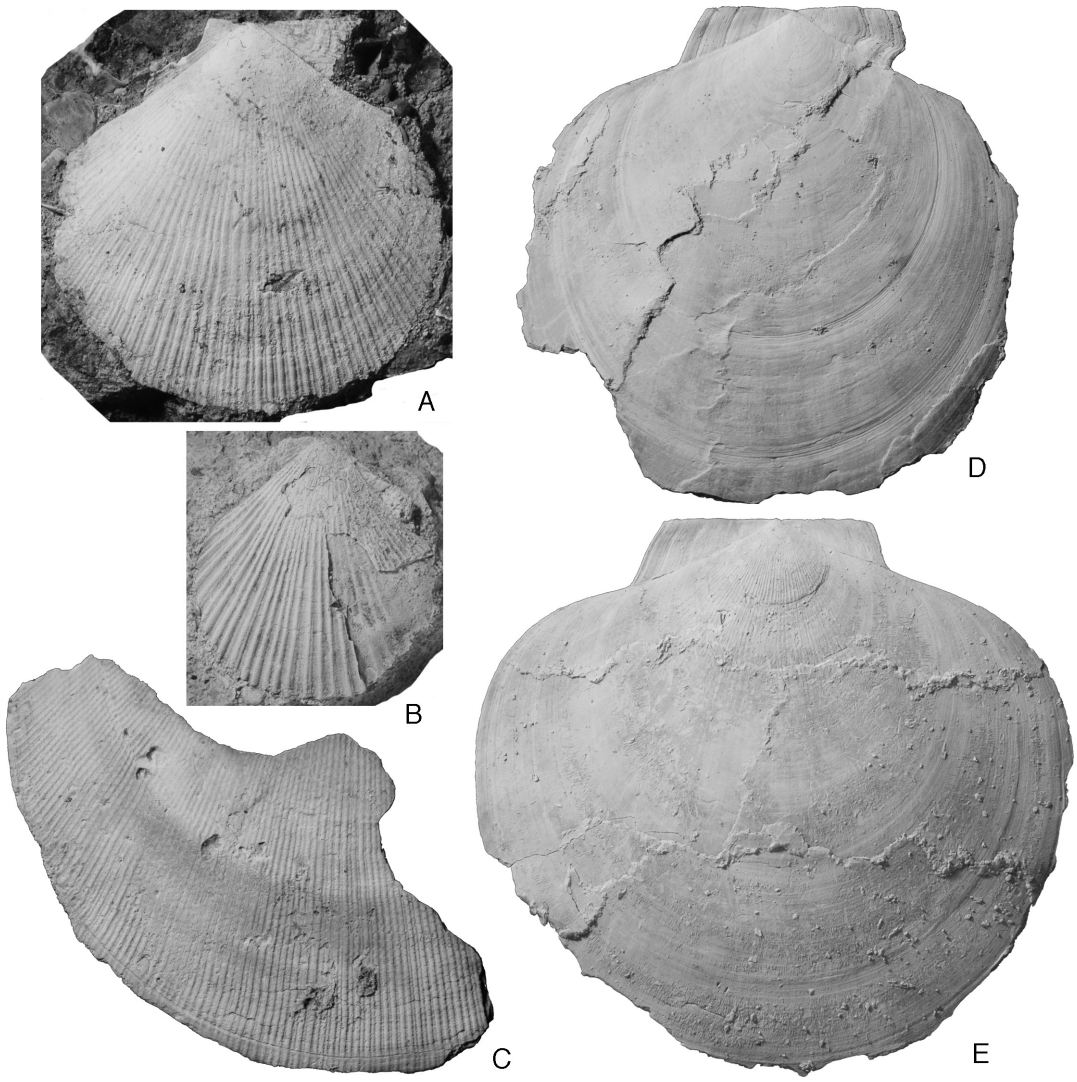


Fig. 22. **A**. *Nipponopecten protomollitus* (Nomura). RV, IGUT 14305, 51.0×52.0×7.7 mm, loc. Kar-1, Kobana Fm. [exterior (×1)]. **B.** *Chlamys* (*Leochlamys*) sp. cf. *C.* (*L.*) *arakawai* (Nomura). LV, IGUT 14304, 26.2+×28.4 mm , Kar-1, Kobana Fm. [exterior (×1)]. **C**. *Nipponopecten* sp. cf. *N. akihoensis* (Matsumoto). RV?, IGUT 14308, loc. Bat-1, Kobana Fm., [exterior (×1)]. **D, E**. *Miyagipecten matsumoriensis* Masuda. D: RV, IGUT 14354, 108.0+×110.0+×5.8 mm, loc. Bat-3, Ogane Fm. [exterior (×0.5)]. E: LV, IGUT 14358, 130.6×122.8+×7.0 mm, loc. Bat-3, Ogane Fm. [exterior (×0.5)].

Genus ***Miyagipecten*** Masuda, 1952

Miyagipecten matsumoriensis Masuda, 1952

(Figs. 22D, E)

Pecten (*Pseudamussium*) *akihoënsis* Matsumoto: Nomura and Hatai, 1936, p. 121, pl. 16, fig. 2 [not of Matsumoto, 1930].

Miyagipecten matsumoriensis Masuda, 1952, p. 251–252, pl. 24, figs. 4a–7b; Matsubara, 1996, p. 24–25, pl. 1, figs. 3a, b

[contains synonymies].

Chlamys (*Miyagipecten*) *matsumoriensis* (Masuda): Iwasaki, 1970, p. 397, pl. 4, fig. 4.

Material.—Two specimens (IGUT 14354, 14358) from loc. Bat-3.

Remarks.—The specimens examined are characterized by their very large shell size (L＜135 mm), very thin shell, weak convexity, large apical angle (137°) and almost smooth disc exterior except for LV umbonal part with fine radial ribs. These shell characteristics agree well with those of *Miyagipecten matsumoriensis* Masuda, 1952 and there are no comparable fossil and Recent species in Japan.

Occurrence.—Ogane Fm, loc. Bat-3.

Stratigraphic and geographic range.—This species is reported in upper Middle Miocene to uppermost Miocene formations of Honshu. Its fossil occurrence was summarized by Matsubara (1996).

Family Anomiidae Rafinesque, 1815
Genus ***Anomia*** Linnaeus, 1758

Anomia? sp.

Anomiidae gen. et sp. indet.: Kurihara, 1999, Table 2.

Occurrence.—Arakawa Fm., locs. Iwd-1, 3G.

Family Lucinidae J. Fleming, 1828
Genus ***Lucinoma*** Dall, 1901

Lucinoma acutilineatum (Conrad, 1849)

(Fig. 23B, C)

Lucina acutilineata Conrad, 1849, p. 725, pl. 18, figs. 2, 2a, 2b.

Lucinoma acutilineata (Conrad): Moore, 1988, p. D16–D17, pl. 4, figs. 1–3, 6; Noda *et al*., 1995, p. 61–62, figs. 9.5, 9.6, 16.17, 16.21: Matsubara, 1995, p. 325, fig. 1.13 [contains synonymies].

Material.—Six specimens (GMNH PI2062–2067) from loc. Tom-HN6.

Remarks.—This species occurs autochthonously in the Haraichi and Shogunzawa Formations and is commonly preserved as a longitudinally depressed form in siltstone.

Occurrence.—Haraichi Fm., loc. Tom-3, 4, 5, 7, 26, 16, 10, 11, 12, 13, HN6; Ogane Fm., loc. Kar-10, 19; Tanokura Fm., loc. Kar-33; Shogunzawa Fm., locs. Iwd-26, 27, 32, 33; Hatoyama Fm., loc. Iwd-42.

Stratigraphic and geographic range.—This species ranges from the Lower Miocene to Holocene in the western and eastern margins of the North Pacific.

Lucinoma sp.

Lucinoma sp.: Kurihara, 1999, fig. 6.21.

Material.—One specimen (NMNS PM25162) from loc. Iwd-13U; one specimen (NMNS PM25163) from loc. Iwd-15.

Remarks.—The specimens examined are small (L＜20 mm) in shell size and exhibit densely spaced commarginal lamellae. They are too poorly preserved to allow its specific identification.

Occurrence.—Arakawa Fm., loc. Iwd-3G; Negishi Fm., locs. Iwd-13U, 15, 16, 18, 22.

Family Ungulinidae H. Adams and A. Adams, 1857
Genus ***Felaniella*** Dall, 1899

Felaniella sp. cf. ***F. usta*** (Gould, 1861)

Compare.—
Mysia (*Felania*) *usta* Gould, 1861, p. 32.
Felaniella usta (Gould): Noda *et al*., 1993, p. 150–152, figs. 20.1a–20.2b; Matsukuma, 2000b, p. 935, pl. 465, fig. 4.

Material.—One specimen (GMNH PI2187) from loc. Tom-HN8.

Remarks.—This species is represented by a poorly preserved conjoined specimen. The small shell size (L 18.8 mm), ovate shell outline and almost smooth shell exterior surface suggest that it may be referable to *Felaniella usta* (Gould, 1861).

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—*F. usta* is known to occur from upper Lower Miocene to Holocene Formations in Japan. Modern distribution of this species is reported at depths of 10 to 50 m, central Honshu to Okhotsk Sea (Matsukuma, 2000b).

Family Thyasiridae Dall, 1900
Genus ***Conchocele*** Gabb, 1866

Conchocele bisecta (Conrad, 1849)

(Fig. 23D)

Venus bisecta Conrad, 1849, p. 724.
Conchocele bisecta: Noda, 1992, p. 66–68, pl. 1, figs. 22, 23; Noda *et al*., 1993, p. 149–150, figs. 19.8–19.13.
Conchocele sp.: Kurihara, 1999, table 2.

Material.—Six specimens (NMNS PM25164, 25165) from loc. Tom-35.

Remarks.—The large shell size (L<90 mm), subquadrate shell form, relatively large posterior portion separated by the radial sulcus of the specimens examined are identical with those of

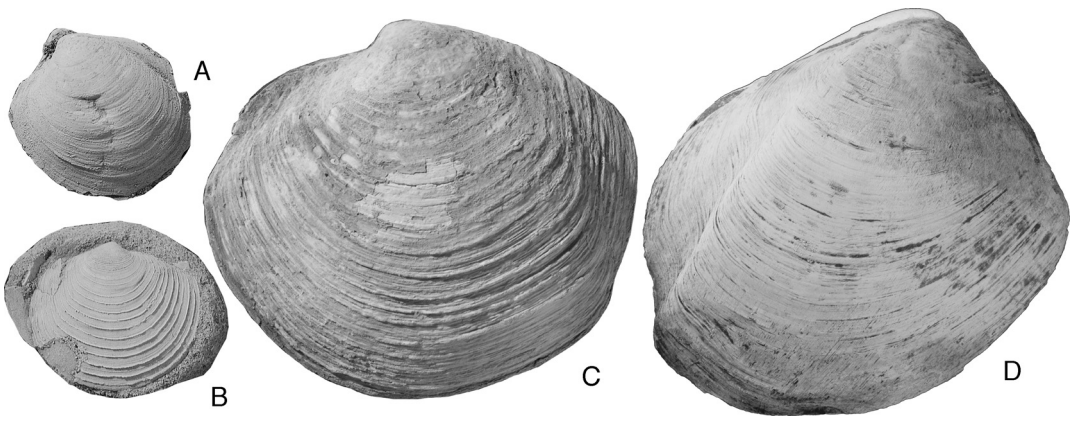


Fig. 23. **A**. *Conchocele*? sp. CV, GMNH PI2188, 16.4+×14.8+×8.4 mm, loc.Tom-HN8, Itahana Fm. [left view (×1.5)]. **B, C**. *Lucinoma acutilineatum* (Conrad). B: RV, GMNH PI-2185, 23.2×19.8 mm, loc. Tom-HN8, Itahana Fm. [exterior (×1)] . C: CV, GMNH PI-2062, 67.9×58.6 ×32.0 mm, loc. Tom-HN6, Haraichi Fm. [left view (×0.85)]. **D.** *Conchocele bisecta* (Conrad). CV, NMNS PM25164, 67.2×62.6×40.0 mm, loc. Tom-35, Haraichi Fm. [right view (×0.85)].

Conchocele bisecta (Conrad, 1849). *Conchocele* sp. of Kurihara (1999) from the Arakawa Formation may be a fragment of this species.

Occurrence.—Haraichi Fm., locs. Tom-11, 30, 35, HN4; Arakawa Fm., loc. Iwd-3G.

Stratigraphic and geographic range.—This species is widely reported from the Eocene to Holocene formations in the western and eastern margins of North Pacific (see Noda, 1992). Modern occurrence of this species is reported at depths of 50 to 750 m, Sea of Okhotsk to Sagami Bay, the Sea of Japan, and the Pribilof Islands (57°N) to off Humboldt Bay, California (Coan *et al*., 2000).

Conchocele? sp.

(Fig. 23A)

Material.—One specimen (GMNH PI2188) from loc. Tom-HN8.

Remarks.—This unnamed species is represented by a single conjoined specimen from the Itahana Formation. Its small shell size, thin shell thickness and rounded ovate form suggest that it may be an immature form of *Conchocele* species or a mature form of other thyasirids.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Family Carditidae J. Fleming, 1828
Subfamily Carditamerinae Chavan, 1969
Genus ***Cyclocardia*** Conrad, 1867

Cyclocardia sp. cf. ***C. siogamensis*** (Nomura, 1935)

Compare.—
Venericardia siogamensis Nomura, 1935c, p. 212–213, pl. 17, figs. 8–11.
Cyclocardia siogamensis (Nomura): Nakagawa, 1998, p. 131, figs. 24.19–24.20 [contains synonymies].

Material.—Four specimens (NMNS PM25166, 25167) from loc. Iwd-10.

Remarks.—The moderate shell size (L<40 mm), subovate shell form and about 20 broad radial ribs separated by narrower interspaces suggest that the specimens examined may be referable to *Cyclocardia siogamensis* (Nomura, 1935). They are not suitable for illustration because of their poor preservation.

Occurrence.—Kobana Fm., locs. Kar-40, 41; Ogane Fm., loc. Kar-27; Negishi Fm., locs. Iwd-10, 18, 19.

Stratigraphic and geographic range.—The compared species, *Cyclocardia siogamensis* is reported in upper Lower to middle Middle Miocene strata in Honshu.

Cyclocardia* (*Cyclocardia*)** sp. aff. ***C. onukii (Masuda and Takegawa, 1965)

(Fig. 24D)

Compare.—
Venericardia onukii Masuda and Takegawa, 1965, p. 12, pl. 1, figs. 15–22.

Material.—One specimen (NMNS PM25168) from loc. Tom-45a.

Remarks.—The specimen examined resembles *Cyclocardia onukii* (Masuda and Takegawa, 1965) in its small shell size (L 11.5 mm, H 10.0 mm), rounded radial ribs crossed by distinct growth lines forming a somewhat granulated appearance. However, the present species differs

from *C. onukii* in the shell outline and number of radial ribs. *C. onukii* is distinctly higher than long and about 20 radial ribs, whereas the Itahana specimen has an almost equi-dimensional shell outline and 18 radial ribs.

Occurrence.—Itahana Fm., loc. Tom-45a.

Stratigraphic and geographic range.—*C. onukii* is known only from the Upper Miocene Fukuda Formation, Miyagi Prefecture.

Genus ***Miodontiscus*** Dall, 1903

Miodontiscus prolongatus (Carpenter, 1864)

(Fig. 24A–C)

Miodon prolongatus Carpenter, 1864, p. 642

Miodontiscus prolongatus (Carpenter): Palmer, 1958, p. 83–84, pl. 8, figs. 1–7; Scarlato, 1981, p. 339–340, fig. 307; Popov, 1983, p. 79, pl. 11, figs. 12–14; Marincovich, 1983, p. 88–89, pl. 14, fig. 11; Coan *et al*., 2000, p. 305–306, pl. 61, 2 figs.

Venericardia nakamurai Yokoyama, 1923a, p. 5–6, pl. 1, fig. 9; Yokoyama, 1926b, p. 298, pl. 36, fig. 3.

Miodontiscus nakamurai (Yokoyama): Ogasawara, 1977, p. 110–111, pl. 10, figs. 3a, b, pl. 11, figs. 1a–2b; Baba, 1990, p. 274–275, pl. 32, fig. 9 [?].

Miodontiscus prolongatus nakamurai (Yokoyama): Habe, 1977, p. 159, pl. 29, figs. 12, 13.

Venericardia prolongatus nakamurai Yokoyama: Takahashi, 1986, pl. 14, fig. 7.

Cardita (*Miodontiscus*) *nakamurai annakensis* Oinomikado, 1938, p. 674, pl. 20, figs. 7, 8.

Not *Miodontiscus annakensis* (Oinomikado): Scarlato, 1981, p. 340, photos. 308, 309; Popov, 1983, p. 80, pl. 11, figs. 15–18; Okutani *et al*., 2009, p. 209–210, fig. 4H [= *Miodontiscus* sp. nov.?].

Material.—Two specimens (GMNH PI2189, 2190) from loc. Tom-HN8; four specimens (NMNS PM25169–25171) from loc. Tom-45a.

Remarks.—I believe that the specimens examined are conspecific with the poorly known subspecies *Cardita* (*Miodontiscus*) *nakamurai annakensis* Oinomikado, 1938, originally described from the Itahana Formation. Although Oinomikado (1938) described the type locality as "Annaka-mati", Hatai and Nisiyama (1952) gave its detailed information as "cliff and floor of the small river at Namerisawa, a short distance W of Komata, Annaka-mati". Oinomikado (1938) stated that the only difference between his subspecies and the Pliocene to Recent *Miodontiscus nakamurai* Yokoyama, 1923 is the number of radial ribs; 14–16 in *M. nakamurai annakensis* whereas 10–12 in *M. nakamurai*. The specimens examined have 12 or 13 radial ribs. The holotype of Oinomikado's subspecies cannot be re-examined because it was lost during World War II. Ogasawara (1977) reported that the number of radial ribs ranges 9–12 or 13 in *M. nakamurai* from the Pleistocene Omma Formation, Ishikawa Prefecture. Although the maximum shell size of the Itahana specimens (H 4.3 mm) is smaller than that of the Omma specimens (H 7.4 mm), there is no remarkable difference in shell form and exterior sculpture between them. Moreover, Scarlato (1981) and Coan *et al.* (2000) recognized that *M. nakamurai* and the eastern North Pacific *Miodontiscus prolongatus* (Carpenter, 1864) are conspecific. Therefore, I regard *M. nakakurai* and *M. nakamurai annakensis* as junior synonyms of *M. prolongatus*.

The modern specimens identified by Scarlato (1981), Popov (1983) and Okutani *et al*. (2009) as *M. annakensis* from the Russian Far East and off Sanriku clearly differs from this species in having more number of the radial ribs (19–23). These specimens cannot be referred to any known species of *Miodontiscus* and may represent a new species.

Occurrence.—Itahana Fm., locs. Tom-HN8, 45a.

Stratigraphic and geographic range.—The Itahana specimens represent the oldest record of

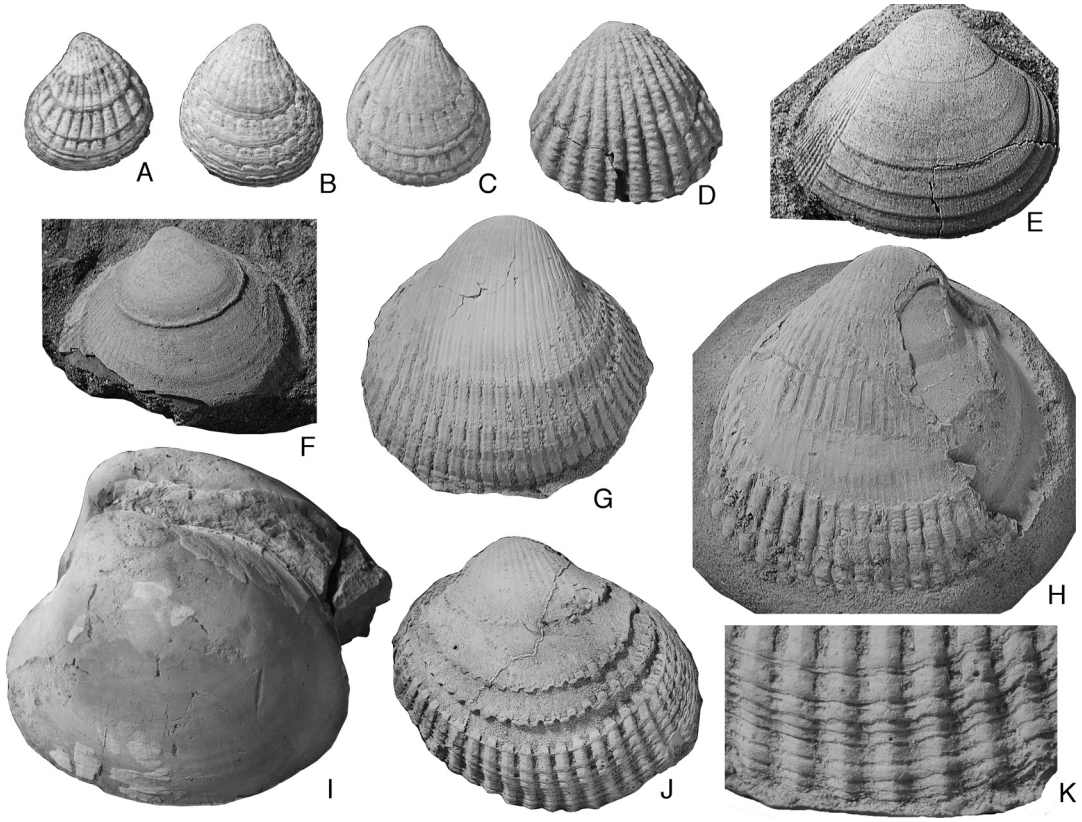


Fig. 24. **A–C**. *Miodontiscus prolongatus* (Carpenter). A: LV, NMNS PM25169, 3.4×3.6×1.2 mm, loc. Tom-45a, Itahana Fm. [exterior (×5)]. B: RV, GMNH PI2189, 3.8×4.3 mm, loc. Tom-HN8, Itahana Fm. [exterior (×5)]. C: RV, NMNS PM25170, 3.8×4.3 mm, loc. Tom-45a, Itahana Fm. [exterior (×5)]. **D**. *Cyclocardia* sp. aff. *C. onukii* Masuda and Takegawa. LV, NMNS PM25168, 10.5×10.0×3.4 mm, loc. 45a, Itahana Fm. [exterior (×2.5)]. **E**. *Nemocardium* (*Keenaea*) *samarangae* Makiyama. RV, GMNH PI2196, 24.6×20.6×8.6 mm, loc.Tom-HN8, Itahana Fm., [exterior (×1.4)]. **F, I**. *Serripes groenlandicus* (Mohr). F: LV, GMNH PI2195, 32.0+×22.6+ mm, loc.Tom-HN8, Itahana Fm. [exterior (×1)]. I: LV, GMNH PI2076, 73.4×63.5×23.5 mm, loc. Tom10, Haraichi Fm. [inner mold (×0.6)]. **G, H**. *Clinocardium* (*Clinocardium*) *shiobarense* (Yokoyama). G: RV, GMNH PI2192, 29.8×27.9×10,5 mm, loc. Tom-HN8, Itahana Fm. [exterior (×1.5)]. H: RV, GMNH PI2191, 58.3+×56.0×19.0 mm, loc. Tom-HN8, Itahana Fm. [exterior (×0.9)]. **J, K**. *Clinocardium* (*Ciliatocardium*) *iwasiroense* (Nomura). RV, IGUT 14362, 40.6×35.8 mm, loc. Kar-10. Ogane Fm. [J, exterior, rubber cast (×1); K, roof shaped radial ribs near the ventral margin, rubber cast (×2.5)].

the genus and species in Japan. The oldest occurrence of this species is in the lower Upper Miocene such as the Itahana Formation in Japan, the Etolonskaya Suite in Kamchatka, Russia (Kafanov *et al*., 2000, 2001) and the Tachilni Formation in Alaska, U. S. A. (Marincovich, 1983). Modern occurrence of this species is reported at depths of 100 to 115 m, off Nemuro, Hokkaido to off Noto Peninsula (Higo and Goto, 1993), at depths of 20 to 76 m, off Nemuro (Scarlato, 1981), and from Alaska to California (Coan *et al*., 2000).

Family Vesicomyidae Dall and Simpson, 1901
Genus ***Calyptogena*** Dall, 1891

Calyptogena? sp.

Calyptogena? sp.: Kurihara, 2000, p. 12, pl. 4, figs. 11, 12.

Material.—Four specimens (GMNH PI2040–2043) from loc. Tom-1.
Occurrence.—Haratajino Fm., loc. Tom-1.

Family Cardiidae Lamarck, 1809
Subfamily Clinocardiinae Kafanov, 1975
Genus ***Clinocardium*** Keen, 1936
Subgenus ***Clinocardium*** s. s.

Clinocardium (***Clinocardium***) ***shiobarense*** (Yokoyama, 1926)

(Fig. 24G, H)

Cardium shiobarense Yokoyama, 1926a, p. 134, pl. 20, figs. 2–5.
Leavicardium shiobarense (Yokoyama): Iwasaki, 1970, p. 402, pl. 1, fig. 19.
"*Dinocardium*" *shiobarense* (Yokoyama): Amano, 1983, p. 45–46, pl. 3, fig. 15 [contains synonymies].
Clinocardium shiobarense (Yokoyama): Hayashi *et al*., 2004, table 2.

Material.—Three specimens (GMNH PI2191–2193) from loc. Tom-HN8; two specimens (NMNS PM25172) from loc. Uts-2b.

Remarks.—The specimens assigned here to *Clinocardium* (*Clinocardium*) *shiobarense* (Yokoyama, 1926) have 35–39, rounded, strong radial ribs. According to Iwasaki (1970), the radial rib of this species from the Kubota Formation, Fukushima Prefecture ranges 33–42 and is 38 in average. The generic allocation of this species is unsettled. On the similarity of radial rib characteristics, I tentatively assigned here this species to the genus *Clinocardium* Keen, 1936 (type species: *Cardium nuttalli* Conrad, 1837 by original designation) and the subgenus *Clinocardium* s. s.

Occurrence.—Itahana Fm., loc. Tom-HN8; Oya Fm., loc. Uts-1, 2b.

Stratigraphic and geographic range.—This species is reported in lower Middle Miocene to lower Upper Miocene strata in Honshu and Hokkaido (see Amano, 1983).

Subgenus ***Ciliatocardium*** Kafanov, 1974

Clinocardium (***Ciliatocardium***) ***iwasiroense*** (Nomura, 1935)

(Fig. 24J, K)

Cardium (*Cerastoderma*) *iwasiroense* Nomura, 1935a, p. 113–114, pl. 6, figs. 1, 2.
Cardium (*Clinocardium*) *iwasiroense* Nomura: Otuka, 1943, p. 55–56.
Clinocardium iwasiroense (Nomura): Zinbo, 1973, pl. 14, fig. 7.
Keenocardium (*Keenocardium*) *iwasiroense* (Nomura): Kafanov, 2000, p. 110–111, pl. 1 fig. 2.

Material.— Three specimens (IGUT 14361–14363) from loc. Kar-10; three specimens (NMNS PM25173) from loc. Kmt-1.

Remarks.—The specimens examined exhibit a variable shell outline and have somewhat roof-shaped radial ribs. Only two cast specimens are available for counting the number of radial ribs and both bear 29 ribs. In the shell size, form and number of the radial ribs, the specimens exam-

ined are identical with the syntypes of *Cardium* (*Cerastoderma*) *iwasiroense* Nomura, 1935 from the Upper Miocene Shiotsubo Formation, Fukushima Prefecture. The roof-shaped rib profile suggests that this species belongs to the genus *Clinocardium* Keen, 1936 and the subgenus *Ciliatocardium* Kafanov, 1974 (type species: *Cardium ciliatum* Fabricius, 1780 by original designation). Although Nomura (1935a) noted that this species has "rounded radial ribs", I doubt that his description is based only on the internal molds. This species is distinguished from its closely allied extant species, *Clinocardium* (*Ciliatocardium*) *ciliatum* (Fabricius, 1780) by the less number of radial ribs. The former species has 29 (Ogane specimens examined herein) or 30–33 radial ribs (Shiotsubo specimens: Nomura, 1935a) whereas the latter has about 35.

Occurrence.—Ogane Fm., locs. Kar-8, 10, 12, 13, 14, 19; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—Lower Upper Miocene: Kurosawa Fm., Akita Pref.; Shiotsubo Fm., Fukushima Pref.; Utsutoge Fm., Yamagata Pref.

Genus ***Serripes*** Gould, 1814

Serripes groenlandicus (Mohr, 1786)

(Fig. 24F, I)

Cardium groenlandicum Mohr, 1786, p. 129.
Serripes groenlandicus (Bruguiére): Matsukuma, 2000c, p. 957, pl. 476, fig. 38.
Serripes (*Serripes*) *groenlandicus* (Mohr): Coan *et al*., 2000, p. 355–356, pl. 74, 2 figs.
Serripes groenlandicus (Mohr): Kafanov, 2003, p. 3–5, pl. 1, figs. 1–15, pl. 5, figs. 1, 3–8 [contains synonymies].
? *Serripes groenlandicus* (Bruguiére): Hirayama, 1954, p. 67, pl. 4, fig. 3.

Material.—One specimen (GMNH PI2069) from loc. Tom-HN4; one specimen (GMNH PI2076) from loc. Tom-10; one specimen (GMNH PI2195) from loc. Tom-HN8; four specimens (IGUT 14371) from loc. Kar-11.

Remarks.—The specimens examined are characterized by their subquadrate, well-inflated shell, prominent, prosogyrated umbones and almost smooth exterior surface except several weak radial ornaments at both anterior and posterior extremities. These shell features show that they are safely referable to *Serripes groenlandicus* (Mohr, 1786).

Occurrence.—Haraichi Fm., locs. Tom-10, 14, 15; Ogane Fm., loc. Kar-19; Tanokura Fm., locs. Kar-11, 33.

Stratigraphic and geographic range.—This species ranges from the Lower Miocene to Holocene. The fossil occurrence of this species was summarized by Kafanov (2003). This species is currently reported to occur Point Barrow, the Chukchi Sea, throughout the Bering Sea shelf, to Amchitka Island, Aleutian Islands, Alaska, south to Puget Sound, Washington; in the North Atlantic from Greenland to New England; in the western Pacific south to Japan in intertidal zone down to 80 m (Coan *et al*., 2000).

Subfamily Laevicardiinae Keen, 1936
Genus ***Nemocardium*** Meek, 1876
Subgenus ***Keenaea*** Habe, 1952

Nemocadium* (*Keenaea*) *samarangae (Makiyama, 1934)

(Fig. 24E)

Cardium modestum Adams and Reeve, 1850, p. 77, pl. 22, fig. 6 [not of Philippi, 1849].

Cardium (*Nemocardium*) *samarangae* Makiyama, 1934, p. 143.
Nemocardium (*Keenaea*) *samarangae* (Makiyama): Shuto, 1960, p. 214–216, pl. 25, figs. 1–6, 19, 23, 24; Noda *et al*., 1993, p. 154, fig. 29.12 [contains synonymies].
Keenaea samarangae (Makiyama): Matsukuma, 2000c, p. 955, pl. 475, fig. 30.

Material.—Twenty-five specimens (GMNH PI2197–2221) from loc. Tom-HN8; nine specimens (NMNS PM25174) from loc. Tom-45a; 12 specimens (NMNS PM25175) from loc. Kar-40; five specimens (IGUT 14315) from loc. Kar-41; two specimens (NMNS PM25176) from loc. Iwd-13U.

Remarks.—The specimens examined are characterized by their small (L＜28 mm), well-inflated shell and fine distinct radial threads on the posterior slope. These shell features indicate that they are safely assignable to *Nemocardium* (*Keenaea*) *samarangae* Makiyama, 1934.

Occurrence.—Itahana Fm., loc. Tom-HN8, 45a; Kobana Fm., locs. Kar-39, 40, 41; Negishi Fm., loc. Iwd-13U.

Stratigraphic and geographic range.—This species is reported in Middle Miocene to Holocene strata in Kyushu and Honshu. The specimens from the Negishi and Kobana Formations represent the oldest record of this species. In modern seas, this species is known to occur at depths of 50–300 m, from off Boso Peninsula to East China Sea (Matsukuma, 2000c).

Family Veneridae Rafinesque, 1815
Subfamily Venerinae Rafinesque, 1815
Genus ***Venus*** Linnaeus, 1758

Venus? sp.

Venus sp.: Hayashi *et al*., 2004, table 2.

Material.—Three specimens (NMNS PM25177) from loc. Iwd-10.

Remarks.—The specimens examined are characterized by their small (L＜55 mm), subtrigonal, well-inflated shell and exterior ornaments consisting of coarse commarginal undulations and fine radial striations. Its preservation is too poor to allow positive identification to the genus.

Occurrence.—Negishi Fm., locs. Iwd-9, 10, 13U; Oya Fm., loc. Uts-3.

Genus ***Securella*** Parker, 1949

Remarks.—The Pliocene to Holocene *Venus stimpsoni* Gould, 1861, and its related fossil species from Japan have been assigned to the genus *Mercenaria* Schumacher, 1817 (type species: *Mercenaria violacea* Schumacher, 1817 [＝*Venus mercenaria* Linnaeus, 1758] by monotypy). However, Moore (1963, p. 74) suggested that *V. stimpsoni* is referable to *Securella* Parker, 1949 (type species: *Venus securis* Schumard, 1858 by original designation) rather than to *Mercenaria* because it does not have a rugose nymph plate characteristic of *Mercenaria*. Harte (1998) is the first one who combined *V. stimpsoni* with *Securella*, but she did not give its formal systematic account. On the basis of fossil record, Vermeij (2001) briefly pointed out that *Securella* evidently arose from a warm-water Oligocene species in the southeastern United States related to or congeneric with *Mercenaria*, and not, as Harte (1998) thought, from an Eocene tropical western Pacific species of *Palacamen*. In Japan the fossil record of *Securella* ranges from the latest Early Miocene or earliest Middle Miocene to the Holocene, whereas in the west coast of North America it ranges from the Oligocene to the Pliocene. These fossil records strongly suggest that this genus migrated in the North Pacific from the eastern (American) side to the western (Asian) side

during the Middle Miocene climatic optimum (Amano, 2005) and became regionally extinct only in the eastern (American) side (the northwestern Pacific restriction; Vermeij, 1989). In Japan there are several nominal fossil species assignable to *Securella*, and its taxonomic revision is needed.

Securella yokoyamai (Makiyama, 1927) comb. nov.

(Fig. 25C, D)

Venus yokoyamai Makiyama, 1927, p. 46–47, pl. 2, fig. 8.

Mercenaria yokoyamai (Makiyama): Furusawa *et al*., 1987, p. 69, pl. 2, fig. 4; Noda, 1992, p. 88–89, pl. 3, figs. 7, 8, 10; Nakagawa, 1998, p. 142, figs. 18.7, 18.10.

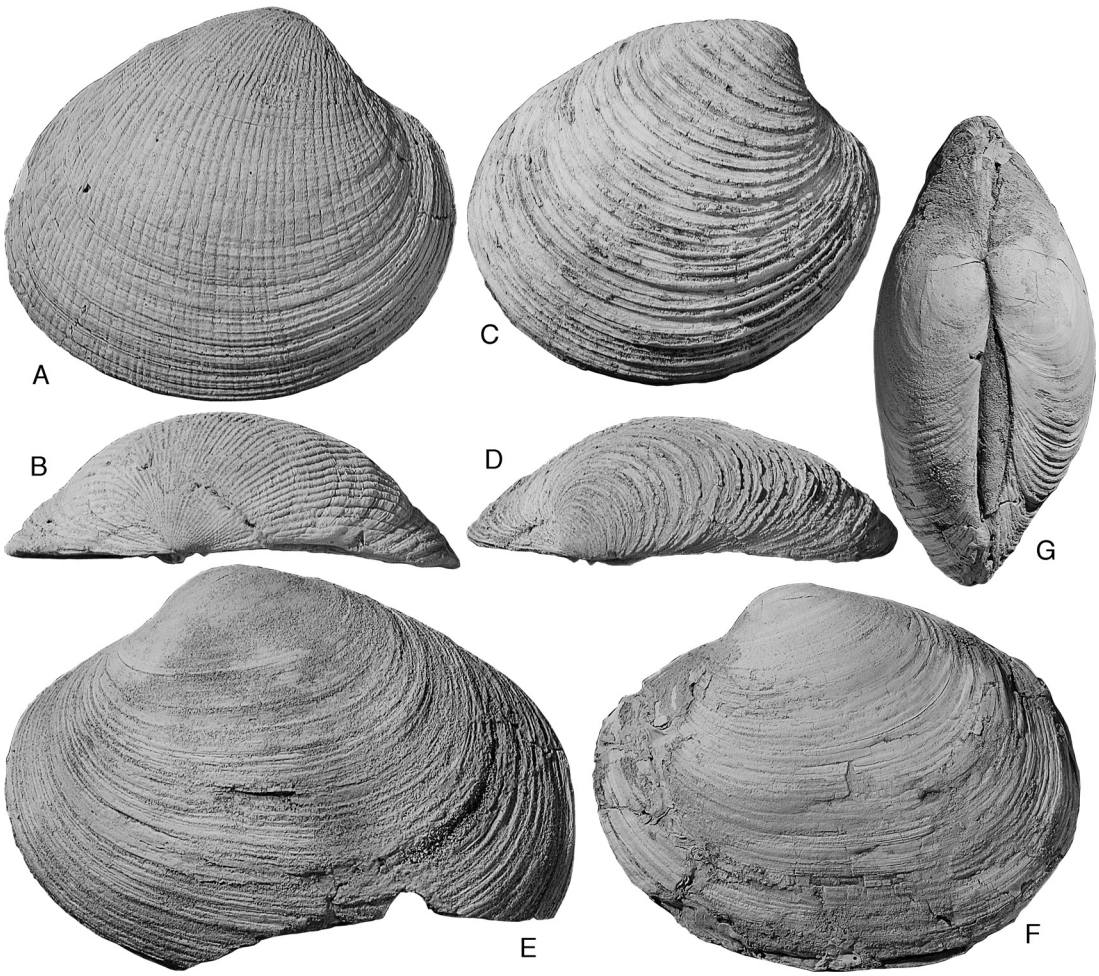


Fig. 25. **A, B**. *Protothaca tateiwai* Makiyama. RV, GMNH PI2228, 62.4×53.6×18.5 mm, loc. Tom-HN8, Itahana Fm. [A, exterior; B, dorsal view (×0.95)]. **C, D**. *Securella yokoyamai* (Makiyama) comb. nov. RV, GMNH PI2222, 57.2×50.0×18.1 mm, loc. Tom-HN8, Itahana Fm. [C, exterior; D, dorsal view (×0.95)]. **E–G**. *Saxidomus purpurata* (Sowerby). E: LV, GMNH PI2238, 80.0×57.9 mm, loc. Tom-HN8, Itahana Fm. [exterior (×0.95)]. F, G: CV, GMNH PI2237, 66.8×53.0×31.0 mm, loc. Tom-HN8, Itahana Fm. [F, left view; G, dorsal view (×0.95)].

Venus (*Chione*) *yokoyamai* Makiyama: Nomura and Hatai, 1936, p. 126, pl. 14, figs. 3, 4.
Mercenaria chitaniana (Yokoyama): Iwasaki, 1970, p. 408–409, pl. 5, fig. 2, pl. 7, figs. 5–7 [not of Yokoyama, 1926].

Material.—Six specimens (GMNH PI2222–2227) from loc. Tom-HN8.

Remarks.—The specimens examined are referable to *Securella makiyamai* (Yokoyama, 1927) in their strongly to moderately inflated shell with distinct commarginal lamellae. Iwasaki (1970) pointed out that this species from the Kubota Formation, Fukushima Prefecture shows a wide range of variation in shell outline. However, the specimens examined are almost constant in shell outline. Following the opinion of Chinzei (1961) on the taxonomy and nomenclature of "*Mercenaria*" in Japan, I distinguish *Securella chitaniana* (Yokoyama, 1926) from this species.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is reported in lower Middle Miocene to Lower Pleistocene strata in Japan. Its fossil occurrence was summarized by Noda (1992).

Genus ***Protothaca*** Dall, 1902

Protothaca tateiwai (Makiyama, 1926)

(Fig. 25A, B)

Chione tateiwai Makiyama, 1926, p. 159–160, pl. 13, figs. 5, 6.
Venerupis (*Protothaca*) *tateiwai* (Makiyama): Makiyama, 1936, p. 211, pl. 4, fig. 1.
Protothaca tateiwai (Makiyama): Nomura and Hatai, 1936, p. 126–127, pl. 14, fig. 7, 8; Iwasaki, 1970, p. 409–410, pl. 1, figs. 5–7; Amano and Sato, 1995, figs. 4.1a, b; Amano *et al*., 2000, pl. 1, figs. 15–16b.
Protothaca (*Protothaca*) *tateiwai* (Makiyama): Lee, 1992, p. 91, figs. 28.2, 28.24, 30.4, 30.6, 30.7.

Material.—Two specimens (GMNH PI2228, 2229) from loc. Tom-HN8.

Remarks.—One large specimen (L 62.4 mm, H 53.6 mm) has 47 almost flat-topped radial ribs that are divided by shallow and much narrower interspaces, while the other small specimen (L 11.7 mm, H 10.7 mm) possesses 34 radial ribs. The extant allied species *Protothaca jedoensis* (Lischke, 1874) clearly differs from *P. tateiwai* in having fewer radial ribs (commonly around 30).

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is reported in Lower Middle Miocene to Lower Pliocene strata in Honshu and Korea. Lower Middle Miocene: Chengogsa Fm., South Korea. ?Middle Miocene: Banko Sandstone, North Korea. Lower Upper Miocene: Kubota Fm., Fukushima Pref. Lower Pliocene: Tentokuji Fm., Akita Pref.; Joshita Fm., Nagano Pref.

Subfamily Dosininae Deshayes, 1853
Genus ***Kaneharaia*** Makiyama, 1936

Kaneharaia sp. cf. ***K. kannoi*** (Masuda, 1963)

Kaneharaia cf. *kannoi* (Masuda): Hayashi *et al*., 2004, table 2.

Remarks.—This unnamed species is represented only by poorly preserved specimens and not suitable for illustration. A summary of description, comparison and distribution of *Kaneharaia kannoi* (Masuda, 1963) was given by Kurihara (2006).

Occurrence.—Oya Fm., loc. Uts-2b.

Kaneharaia kaneharai (Yokoyama, 1926)

(Fig. 26A, B)

Dosinia kaneharai Yokoyama, 1926a, p. 133, pl. 17, figs. 1–5, pl. 18, fig. 2; Nomura and Hatai, 1936, p. 128, pl. 14, fig. 2.

Dosinia (*Kaneharaia*) *kaneharai* Yokoyama: Iwasaki, 1970, p. 405–407, pl. 4, figs. 1, 2.

Kaneharaia kaneharai (Yokoyama): Amano and Hikida, 1999, figs. 3.1, 3.7.

Dosinia (*Kaneharaia*) *kaneharai ouchiensis* Kanno, 1955, p. 82, pl. 13, figs. 1–5; Masuda, 1967, p. 23–24, pl. 1, figs. 5, 6, pl. 2, figs. 2, 6.

Material.—One specimen (GMNH PI2230) from loc. Tom-HN8.

Remarks.—The shell is large (L, H<80 mm), slightly higher than long and moderately inflated. The exterior surface is sculptured with coarse semi-commarginal ribs, which become denser towards the ventral periphery. The escutcheon is ill defined. The specimen examined is very similar to a form known as *Dosinia* (*Kaneharaia*) *kaneharai ouchiensis* Kanno, 1955, which is characterized by a proportionally higher shell outline. However, this form falls within the variation of *Kaneharaia kaneharai* (Yokoyama, 1926) as stated by Amano and Hikida (1999).

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is restricted in the Middle and Upper

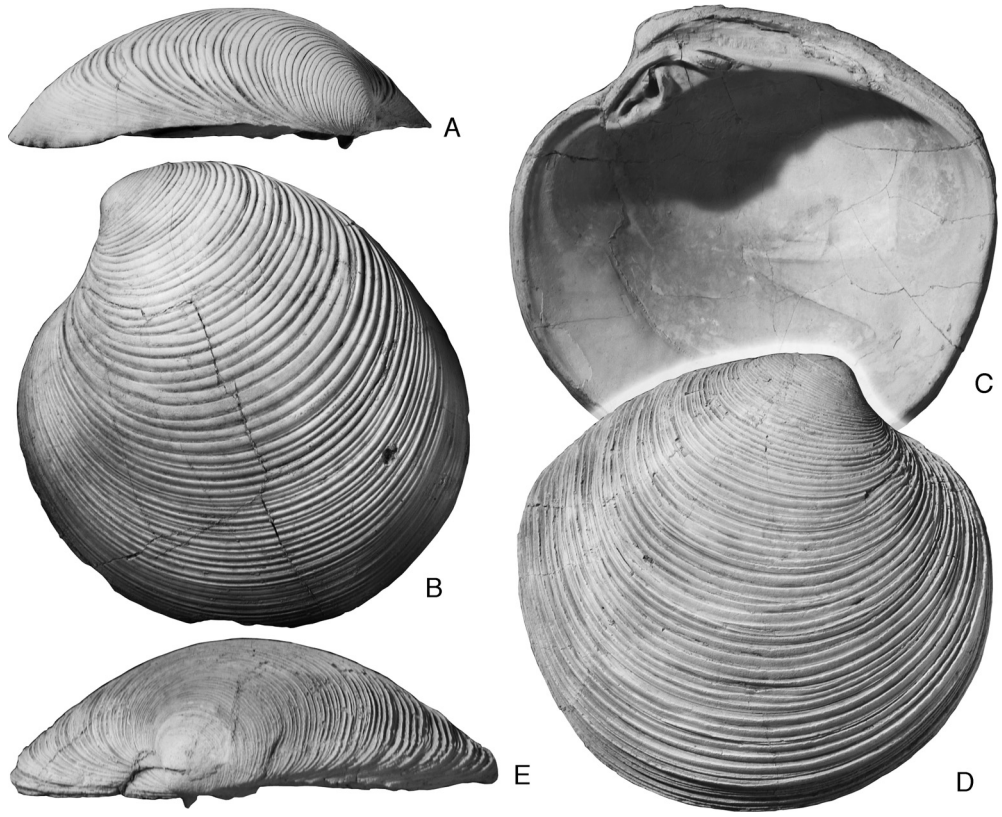


Fig. 26. **A, B**. *Kaneharaia kaneharai* (Yokoyama). LV, GMNH PI2230, 76.6×78.6×23.0 mm, loc.Tom-HN8, Itahana Fm. [A, dorsal view; B, exterior (×0.8)]. **C–E**. *Phacosoma hataii* (Masuda) comb. nov. RV, GMNH PI2231, 64.4×62.4×20.0 mm, loc. Tom-HN8, Itahana Fm. [C, interior; D, exterior; E, dorsal view (×1)].

Miocene of central and northern Honshu (see Amano and Hikida, 1999).

Genus ***Phacosoma*** Jukes-Browne, 1912

Phacosoma hataii (Masuda, 1963) comb. nov.

(Fig. 26C–E)

Dosinia (*Phacosoma*) *hataii* Masuda, 1963, p. 34–35, pl. 6, figs. 1, 2; Noda, 1992, p. 84–85, pl. 14, figs. 2, 4, pl. 15, figs. 1a, b [contains synonymies].
Dosinia (*Phacosoma*) *japonica* (Reeve): Iwasaki, 1970, p. 407–408, pl. 4, figs. 3, 4 [not of Reeve, 1850].

Material.—Six specimens (GMNH PI2231–2236) from loc. Tom-HN8.

Remarks.—The specimens examined are characterized by their large (L, H<70 mm), thick shell, distinct lunule, ill-defined escutcheon and somewhat shallow, trigonal pallial sinus. These shell characteristics agree with the holotype of *Phacosoma hataii* (Masuda, 1963), though the commarginal ribs in the Itahana specimens seem to be more lamellate than those in the holotype from the Kubota Formation, Fukushima Prefecture. This species closely resembles the Pliocene to Recent *Phacosoma japonicum* (Reeve, 1850), but the latter differs in its thinner shell and in having a deeper pallial sinus.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is reported only in lower Upper Miocene strata in central Honshu and Hokkaido (see Noda, 1992).

Phacosoma sp.

Dosinia (*Phacosoma*) sp.: Hayashi *et al*., 2004, table 2.

Occurrence.—Kobana Fm., loc. Kar-1; Oya Fm., loc. Uts-1, 2b.

Subfamily Pitarinae R. B. Stewart, 1930
Genus ***Saxidomus*** Conrad, 1837

Saxidomus purpurata (Sowerby, 1852)

(Fig. 25E–G)

Tapes purpurata Sowerby, 1852, p. 692, pl. 150, figs. 124, 125.
Saxidomus purpuratus (Sowerby): Takayasu, 1980, p. 14–15, pl. 4, figs. 2–5b, pl. 5, fig. 4; Noda *et al*., 1993, p. 164, figs. 21.2a–3b [contains synonymies]; Matsukuma, 2000f, p. 1017, pl. 506, fig. 70.
Saxidomus nuttalli (Conrad): Nomura and Hatai, 1936, p. 127, pl. 14, fig. 9 [not of Conrad, 1837].
Saxidomus cf. *Nuttalli* (Conrad): Nomura, 1940, p. 27, pl. 3, fig. 21 [not of Conrad, 1837].

Material.—Three specimens (GMNH PI2237–2239) from loc. Tom-HN8.

Remarks.—Fossil and Recent *Saxidomus* from Japan is represented only by a single species, *S. purpurata* (Sowerby, 1852). This species is said to differ from its close relative *Saxidomus gigantea* (Deshayes, 1839) living in the eastern North Pacific only in its dark purple interior coloration.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is reported in lower Middle Miocene to Holocene strata of Japan and Korea. The Miocene record of this species is documented from Lower Middle Miocene Moniwa Formation, Miyagi Prefecture (Nomura, 1940), the upper Mid-

dle Miocene Matsue Formation, Shimane Prefecture (Takayasu, 1980) and the lower Upper Miocene Kubota Formation, Fukushima Prefecture (Nomura and Hatai, 1936). Modern distribution is at depths of intertidal zone to 20 m, from southern Hokkaido to Kyushu, Korean Peninsula, and southern coast of mainland of China (Matsukuma, 2000f).

Family Tellinidae Blainville, 1814
Genus ***Bathytellina*** Kuroda and Habe, 1958

Bathytellina? sp.

(Fig. 27A, B)

Material.—Eight specimens (NMNS PM25178) from loc. Iwd-15; 32 specimens (NMNS PM25179–25181) from loc. Iwd-22.

Remarks.—The shell is large (L＜30 mm) for the genus, very thin, compressed, and elongated. The beak is pointed and located at about two sevenths length from the posterior margin. The antero-dorsal margin is almost straight. The anterior margin is narrowly rounded, the ventral margin is long and slightly convex, and the posterior end is slightly truncated. The exterior surface is almost smooth with faint commarginal lines.

These characters suggest that this species belongs to the genus *Bathytellina* Kuroda and Habe, 1958 (type species: *Bathytellina citrocarnea* Kuroda and Habe, 1958 by original designation), but this generic allocation still remains tentative because the interior shell characters are not known due to its fragility. Fossil members of *Bathytellina* have never been reported from Japan.

Occurrence.—Arakawa Fm., loc. Iwd-3G; Negishi Fm., locs. Iwd-15, 18, 21, 22.

Genus ***Macoma*** Leach, 1819
Subgenus ***Macoma*** s. s.

Macoma* (*Macoma*) *optiva (Yokoyama, 1923)

(Fig. 27D, E, G, H)

Tellina optiva Yokoyama, 1923b, p. 6, pl. 2, figs. 3, 4.
Macoma (*Macoma*) *optiva* (Yokoyama): Marincovich, 1983, p. 98–100, pl. 9, figs. 1–10.
Macoma optiva (Yokoyama): Noda, 1992, p. 81–82, pl. 6, figs. 3a, b, 10, 11 [contains synonymies].

Material.—Three specimens (NMNS PM25182) from loc. Tom-11; one specimen (GMNH PI2071) from loc. Tom-HN6; one specimen (GMNH PI-2247) from loc. Tom-HN8; one specimen (NMNS PM25183) from loc. Iwd-22; eight specimens (NMNS PM25184, 25185) from loc. Kmt-1.

Remarks.—*Macoma* (*Macoma*) *optiva* (Yokoyama, 1923) is the most common tellinid bivalve found in the Miocene temperate faunas in the western North Pacific. The specimens examined are characterized by their large shell size (L＜80 mm), large convexity, semi-circular anterior margin, and sharply to moderately sloping posterior dorsal and ventral margins that join the narrow, subtruncate posterior end.

Occurrence.—Haraichi Fm., locs. Tom-11, 32, HN4; Itahana Fm., loc. Tom-HN8; Ogane Fm., locs. Kar-10, 12, 13; Negishi Fm., locs. Iwd-13U, 19, 22; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—This species is reported in Lower to Upper Miocene strata of Honshu, Hokkaido, Sakhalin, Kamchatka, Alaska, Washington and Oregon. The fossil occurrence of this species was summarized by Marincovich (1983) and Noda (1992).

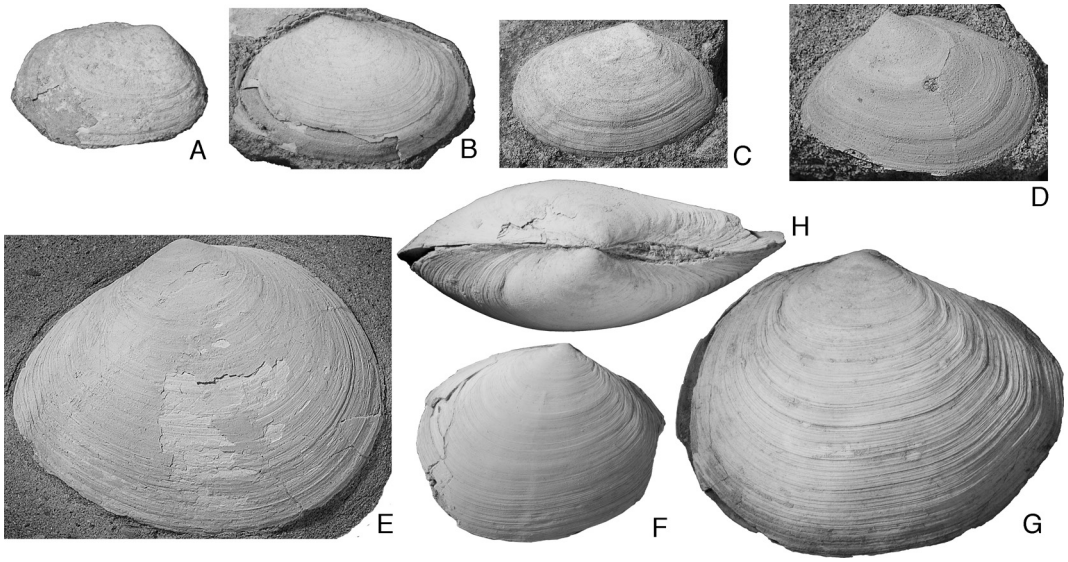


Fig. 27. **A, B**. *Bathytellina*? sp. A: LV, NMNS PM25179, 21.2×13.7 mm, loc. Iwd-22, Negishi Fm. [exterior (×1.2)]. B: RV, 25.8×16.2 mm, NMNS PM25180, loc. Iwd-22, Negishi Fm. [exterior (×1.2)]. **C**. *Macoma* sp. cf. *M.* (*Macoma*) *praetexta* (von Martens). LV, GMNH PI2246, 27.7×17.4 mm, loc. Tom-HN8, Itahana Fm. [exterior (×1)]. **D, E, G, H**. *Macoma* (*Macoma*) *optiva* (Yokoyama). D: LV, GMNH PI2240, 16.4×12.0 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2)]. E: RV, GMNH PI2247, 55.0×45.1 mm, loc. Tom-HN8, Itahana Fm. [exterior (×0.9)]. G, H: CV, NMNS PM25184, 56.9×43.7×21.2 mm, loc. Kmt-1, Tsuchishio Fm. [G, left view; H, dorsal view (×0.9)]. **F**. *Macoma* (*Macoma*) *calcarea* (Gmelin). RV, GMNH PI2070, 49.0+×38.4×15.7 mm, loc. Tom-HN6, Haraichi Fm. [exterior (×0.7)].

Macoma* (*Macoma*) *calcarea (Gmelin, 1791)

(Fig. 27F)

Tellina calcarea Gmelin, 1791, p. 3236.

Macoma calcarea (Gmelin): Noda, 1992, p. 79–80, pl. 6, figs. 2, 5, pl. 16, figs. 2, 4; Matsukuma, 2000e, p. 981, pl. 488, fig. 52.

Macoma (*Macoma*) *calcarea* (Gmelin): Coan, 1971, p. 20–22, pl. 3, fig. 20, pl. 4, figs. 21–24; Coan *et al*., 2000, p. 409, pl. 84, 2 figs.

Macoma (*Macoma*) *calcarea calcarea* (Gmelin): Noda *et al*., 1995, p. 67, figs. 10.7, 10.8, 16.20, 16.22, 17.5.

Material.—One specimen (GMNH PI2072) from loc. Tom-HN6; one specimen (NMNS PM25186) from loc. Tom-32.

Remarks.—*Macoma* (*Macoma*) *calcarea* (Gmelin, 1791) resembles *Macoma* (*Macoma*) *optiva* (Yokoyama, 1923) in general appearance, but differs from the latter in its proportionally elongate shell form, weak shell convexity and more posteriorly situated beaks.

Occurrence.—Haraichi Fm., locs. Tom-32, HN6.

Stratigraphic and geographic range.—This Panarctic and circumboreal species is reported in Lower Miocene to Pleistocene formations in the North Pacific rim. Its fossil occurrence was summarized by Noda (1992). The modern distribution is reported at depths of 10–360 m of Point Barrow, Alaska, through the Bering Sea and southeast Alaska, to off Newport, Oregon; south to Tosa Bay, Japan; to Norway, Iceland, and New York in the Atlantic (Coan *et al*., 2000).

Macoma (***Macoma***) sp. cf. ***M***. (***M.***) ***praetexa*** (von Martens, 1865)

(Fig. 27C)

Compare.—

Tellina praetexa von Martens, 1865, p. 430.

Macoma praetexta (Martens): Ogasawara, 1977, p. 121, pl. 14, fig. 13, pl. 15, figs. 2, 7; Matsukuma, 2000e, p. 981, pl. 488, fig. 55.

Material.—One specimen (GMNH PI2246) from loc. Tom-HN8.

Remarks.—The specimen examined is characterized by its moderate shell size (L 27.7 mm, H 17.4 mm), elongate and less inflated shell form, posteriorly situated beak and blunt ridge from the beak to postero-ventral corner. These characters suggest that the Itahana specimen is likely to be referable to *Macoma* (*Macoma*) *praetexta* (von Martens, 1865). The specimen also resembles some species of *Nitidotellina* Scarlato, 1961 in shell form, but the latter species clearly differs in their small shell size (L＜20 mm).

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—The fossil record of *M*. (*M*.) *praetexta* was previously restricted to the Pleistocene strata in central Honshu. The modern distribution of this species is reported at depths of 10 to 50 m, Taiwan, Kyushu to southern Hokkaido (Matsukuma, 2000e).

Family Solenidae Lamarck, 1809
Genus ***Solen*** Linnaeus, 1758

Solen sp.

Solen sp.: Hayashi *et al*., 2004, table 2.

Occurrence.—Oya Fm., loc. Uts-2b.

Family Pharidae H. Adams and A. Adams, 1858
Genus ***Cultellus*** Schumacher, 1817

Cultellus izumoensis Yokoyama, 1923

(Fig. 29A)

Cultellus izumoensis Yokoyama, 1923b, p. 5, pl. 2, figs. 1a, b.

Cultellus izumoensis izumoensis Yokoyama: Matsubara, 1995, p. 328, fig. 1.19 [contains synonymies].

Cultellus (*Cultellus*) *izumoensis* Yokoyama: Lee, 1992, p. 87, figs. 31.8, 16; Nakagawa, 1998, p. 138–139, figs. 28.1–28.2b.

Material.—Two specimens (GMNH PI2248, 2249) from loc. Tom-HN8.

Remarks.—*Cultellus izumoensis* (Yokoyama, 1923) is a common pharid bivalve in Miocene faunas of Honshu. Its generic assignment to *Cultellus* is conventional, and a detailed examination of shell interior characters such as the hinge dentition and muscle scar patterns is needed for its proper generic assignment.

Occurrence.—Itahana Fm., loc. Tom-HN8; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—This species is reported in Lower to Upper Miocene strata in Honshu and Hokkaido (see Matsubara, 1995).

Genus ***Siliqua*** Megerle von Mühlfeld, 1811

Siliqua sp.

(Fig. 29B)

Material.—One specimen (IGUT 14311) from loc. Kar-2.

Remarks.—The specimen examined is an incomplete internal mold of left valve. The transversely elongate elliptical shell with a vertically directed internal rib suggests that the specimen is assigned to the genus *Siliqua* Megerle von Mühlfeld, 1811.

Family Mactridae Lamarck, 1809
Subfamily Mactrinae Lamarck, 1809
Genus ***Pseudocardium*** Gabb, 1866

Pseudocardium sp. aff. ***P. sachalinense*** (Schrenck, 1861)

(Fig. 28A–C)

Compare.—
Mactra sachalinensis Schrenck, 1861, p. 412.
Pseudocardium sachalinensis (Schrenck): Noda *et al*., 1993, p. 154–155, figs. 20.6–20.9b [contains synonymies].
Pseudocardium sachalinense (Schrenck): Matsukuma, 2000d, p. 965, pl. 480, fig. 12.

Material.—Four specimens (GMNH PI2250–2253) from loc. Tom-HN8.

Remarks.—The specimens examined closely resemble the Miocene to Recent *Pseudocardium sachalinense* (Schrenck, 1861) in their shell size and hinge characters, but differs in shell form. The Itahana specimens have a more robust and elongate shell with the anterior end that is

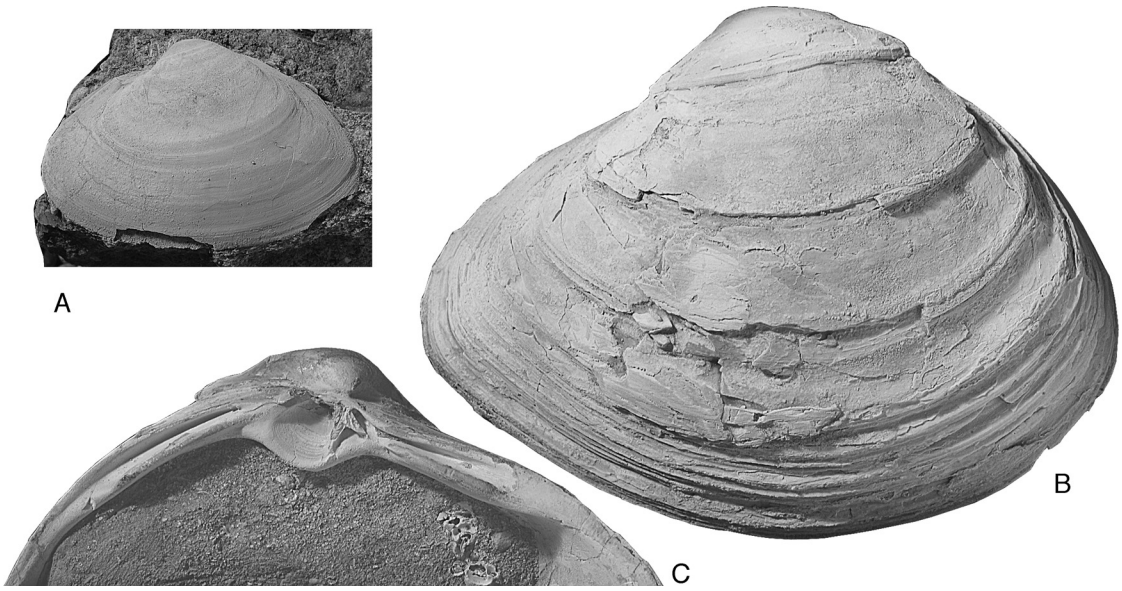


Fig. 28. **A–C.** *Pseudocardium* sp. aff *P. sachalinense* (Schrenck). A: LV, GMNH PI2251, 42.6×28.5 mm, loc. Tom-HN8, Itahana Fm. [exterior (×1)]. B, C: LV, GMNH PI2250, 94.0×70.6×30.0 mm, loc. Tom-HN8, Itahana Fm. [B, exterior; C, hinge plate (×1)].

more narrowly pointed than the typical specimens of *P. sachalinense*. Further comparative study is needed for its proper identification.

Occurrence.—Itahana Fm., loc.Tom-HN8.

Stratigraphic and geographic range.—The oldest occurrence of *P. sachalinense* is known from the Upper Miocene Ogawa Formation, Nagano Prefecture (Amano and Koike, 1993).

Family Myidae Lamack, 1809
Subfamily Myinae Lamarck, 1809
Genus ***Mya*** Linnaeus, 1758
Subgenus ***Mya*** s. s.

Mya (***Mya***) ***cuneiformis*** (Böhm, 1916)

(Fig. 29G, H)

Pleuromya cuneiformis Böhm, 1916, p. 577, pl. 29, figs. 1a–c.
Mya (*Mya*) *cuneiformis* (Böhm): Nakashima, 1999, p. 207–208, figs. 11, 12, 14, 15 [contains synonymies].

Material.—One specimen (IGUT 14367) from loc. Kar-10; three specimens (NMNS PM25187, 25188) from loc. Kmt-1.

Remarks.—The specimens examined clearly show a cuneiform shell outline and irregular growth lines on the shell exterior characteristic of *Mya* (*Mya*) *cuneiformis* (Böhm, 1916). A summary of description, comparison and distribution of this species was given by Nakashima (1999).

Occurrence.—Ogane Fm., loc. Kar-19; Tsuchishio Fm., loc. Kmt-1.

Stratigraphic and geographic range.—This species ranges from the upper Lower Miocene to Pleistocene of Honshu, Hokkaido, Sakhalin and Alaska (see Nakashima, 1999).

Family Corbulidae Lamarck, 1818
Subfamily Corbulinae Lamarck, 1818
Genus ***Anisocorbula*** Iredale, 1930

Anisocorbula venusta (Gould, 1861)

(Fig. 29F)

Corbula venusta Gould, 1861, p. 25.
Anisocorbula venusta (Gould): Baba, 1990, p. 366, pl. 39, fig. 6 [contains synonymies]; Okutani, 2000b, p. 1023, pl. 509, fig. 3.

Material.—One specimen (GMNH PI2255) from loc. Tom-HN8.

Remarks.—A specimen of *Anisocorbula venusta* (Gould, 1861) from the Itahana Formation is characterized by its small shell size (L 7.0 mm, H 4.6 mm), distinct ridge extending from the umbo to postero-ventral corner, well-inflated posterior dorsal margin, and commarginal undulations on the shell exterior.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species ranges from the upper Lower Miocene to Holocene in Japan and Korea. The modern occurrence of this species is reported at depths of intertidal zone to 200 m, southern Hokkaido to Kyushu (Okutani, 2000b).

Family Hiatellidae J. E. Gray, 1824
Subfamily Hiatellinae J. E. Gray, 1824
Genus ***Panopea*** Ménard de la Groye, 1807

Panopea sp.

Panopea sp.: Hayashi *et al*., 2004, table 2.

Material.—One specimen (GMNH PI2256) from loc. Tom-HN8.
Occurrence.—Itahana Fm., loc. Tom-HN8; Oya Fm., loc. Uts-2b.

Genus ***Panomya*** Gray, 1853

Panomya simotomensis Otuka, 1934

(Fig. 29C)

"*Panomya*" *simotomensis* Otuka, 1934, p. 621, pl. 49, figs. 66a, b.
Panomya simotomensis Otuka: Nakashima, 2005, p. 516, figs. 6.1, 6.2 [contains synonymies].

Material.—Two specimens (IGUT 14316) from loc. Kar-41.
Remarks.—The specimens examined are referable to *Panomya simotomensis* Otuka, 1934 in its small shell size (L＜50 mm), elongate shell form and beaks located at one third of shell length from the anterior end. A summary of description, comparison and distribution of this species was given by Nakashima (2005).
Occurrence.—Kobana Fm., locs. Kar-40, 41.
Stratigraphic and geographic range.—This species is reported in Lower Miocene to Lower Pliocene strata in Honshu and Hokkaido (see Nakashima, 2005).

Family Pholadidae Lamarck, 1809
Subfamily Pholadinae Lamarck, 1809
Genus ***Barnea*** Risso, 1826
Subgenus ***Anchomasa*** Leach, 1852

Barnea (***Anchomasa***) sp.

(Fig. 29D)

Material.—One specimen (GMNH PI2436) from loc. Tom-46.
Remarks.—This species is represented by a single rubber cast of an incomplete left valve. It is referable to *Barnea* (*Anchomasa*) in its elongate shell outline and characteristic exterior ornaments consisting of a cancellate pattern with pointed intersections that becomes obsolete towards the posterior end.
Occurrence.—Itahana Fm., loc. Tom-46.

Subgenus ***Umitakea*** Habe, 1952

Barnea (***Umitakea***?) sp.

(Fig. 29E)

Material.—One specimen (GMNH PI2437) from loc. Tom-46.
Remarks.—The specimen examined differs from *Barnea* (*Anchomasa*) sp. discussed above in

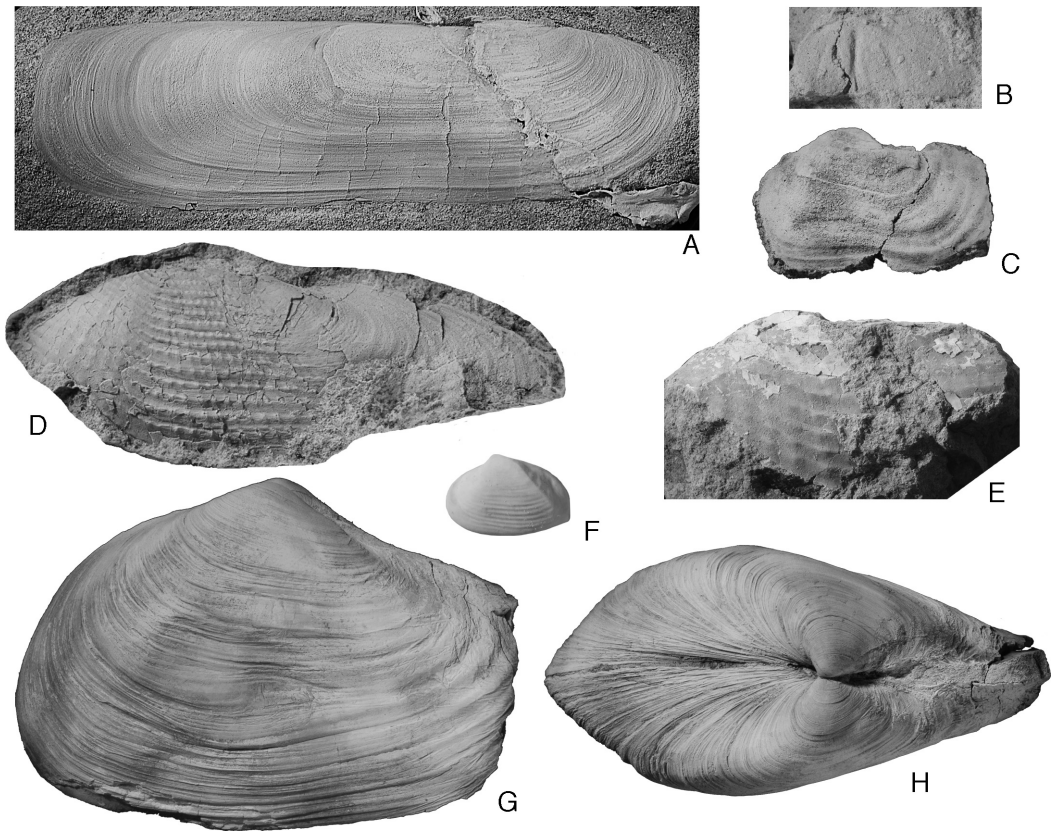


Fig. 29. **A**. *Cultellus izumoensis* Yokoyama. RV, GMNH PI2248, 86.0×25.8 mm, loc. Tom-HN8, Itahana Fm. [exterior (×1)]. **B**. *Siliqua* sp. LV, IGUT 14311, 23.0+×11.3 mm, loc. Kar-2, Kobana Fm. [internal mold (×2)]. **C**. *Panomya simotomensis* (Otuka). CV, IGUT 14316, 38.6×23.9×16.6 mm, loc. Kar-40, Kobana Fm. [left internal mold (×0.8)]. **D**. *Barnea* (*Anchomasa*) sp. LV, GMNH PI2436, 57.0+×19.0+ mm, loc. Tom-46, Itahana Fm. [external rubber cast (×1.2)]. **E**. *Barnea* (*Umitakea*?) sp. LV, GMNH PI2437, 36.7+×18.3 mm, loc. Tom-46, Itahana Fm. [internal mold (×1.2)]. **F**. *Anisocorbula venusta* (Gould). LV, GMNH PI2255, 7.0×4.6×1.6 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2.4)]. **G, H**. *Mya* (*Mya*) *cuneiformis* (Böhm). CV, NMNS PM25187, 67.0+×45.8×32.6 mm, loc. Kmt-1, Tsuchishio Fm. [G, right exterior; H, dorsal view (×1)].

its proportionally shorter shell outline and in having coarser exterior sculpture. These characteristics suggest that the specimen belongs to the subgenus *Umitakea*, but the specimen is too poorly preserved to allow its positive allocation.

Occurrence.—Itahana Fm., loc. Tom-46.

Family Parilimyidae Morton, 1982
Genus ***Panacca*** Dall, 1905

Panacca sp. aff. ***P. trigona*** Sasaki and Okutani, 2007

(Fig. 30A, B)

Compare.—

Panacca trigona Sasaki and Okutani, 2007, p. 372–374, fig. 1.

Material.—One specimen (NMNS PM25189) from loc. Iwd-18.

Remarks.—This species is represented by a single conjoined specimen of which right valve is strongly deformed. The shell is small for the genus, elongate-ovate, moderately inflated, inequilateral, presumably equivalve, fragile, nacreous, and very thin. The umbo is not prominent but pointed. The beak is incurved, slightly prosogyrated, and located one third of the length from the anterior end. The anterior margin is damaged. The postero-dorsal margin is almost straight, passing gradually into the posterior margin. The posterior margin is narrowly rounded. The ventral margin is gently convex but serrated in accordance with the radial threads. No pedal and posterior gape are present. The exterior surface is sculptured by 13, narrow but distinct roof-shaped radial threads which are separated by the broad and shallow furrows, growing closer and weaker posteriorly. The postero-dorsal peripheral part is free from radial ornament. Very weak irregularly-spaced commarginal undulations are developed around the umbo. The escutcheon and lunule are absent. The interior characters are unknown.

This species is quite similar to the Recent *Panacca trigona* Sasaki and Okutani, 2007, but differs from the latter in the mode of radial ornament. In *P. trigona* the interspaces of radial ribs are almost equal in width, whereas in the present species those become closer posteriorly. However, I do not propose a new species name for this taxon until adequate nature of material is obtained.

Occurrence.—Negishi Fm., loc. Iwd-18.

Stratigraphic and geographic range.—*Panacca trigona* is an extremely rare species that is represented by a single valve from upper bathyal depths in Suruga Bay, central Japan (Sasaki and Okutani, 2007).

Genus ***Parilimya*** Melvill and Standen, 1899

Parilimya kawadai Omori, 1952 comb. nov.

(Fig. 30C–F)

Pholadomya kawadai Omori, 1952, p. 23–25, text-figs. 1–3; Hirayama, 1954, p. 70–71, pl. 5, figs. 18, 19.
Not *Pholadomya kawadai* Omori: Iwai, 1959, p. 60, pl. 2, figs. 14a–15; Iwai, 1965, p. 33, pl. 17, figs. 2–3b.
Not *Pholadomya* (*Nipponopanacca*) *kawadai* Omori: Amano *et al*., 1989, p. 112, pl. 20, fig. 24.

Material.—Six specimens (NMNS PM25190-25192) from loc. Iwd-13U.

Remarks.—The specimens examined are all internal molds. The shell is moderate in size for the genus (L＜42 mm), longitudinally elongate-ovate, well inflated, inequilateral, equivalve, presumably nacreous and very thin. The umbo is very prominent. The beak is low, incurved, located near the anterior end. The anterior margin is nearly truncated. The postero-dorsal margin is long, nearly straight with a narrowly rounded posterior margin. The ventral margin is widely convex. Neither anterior nor posterior margin are gaped. The interior surface is sculptured by regularly spaced, distinct commarginal undulations. The escutcheon and lunule are absent. The muscle scar and pallial sinus are unknown.

These characters almost agree with those of *Pholadomya kawadai* Omori, 1952, which was originally described from the Miocene Kobana Formation based on a single internal mold of conjoined valves. Although Omori (1952) stated that the posterior portion of dorsal margin is gaping, there is no gape anteriorly and posteriorly in the specimens examined.

This species cannot be assigned to the genus *Pholadomya* G. B. Sowerby, 1823 (type species:

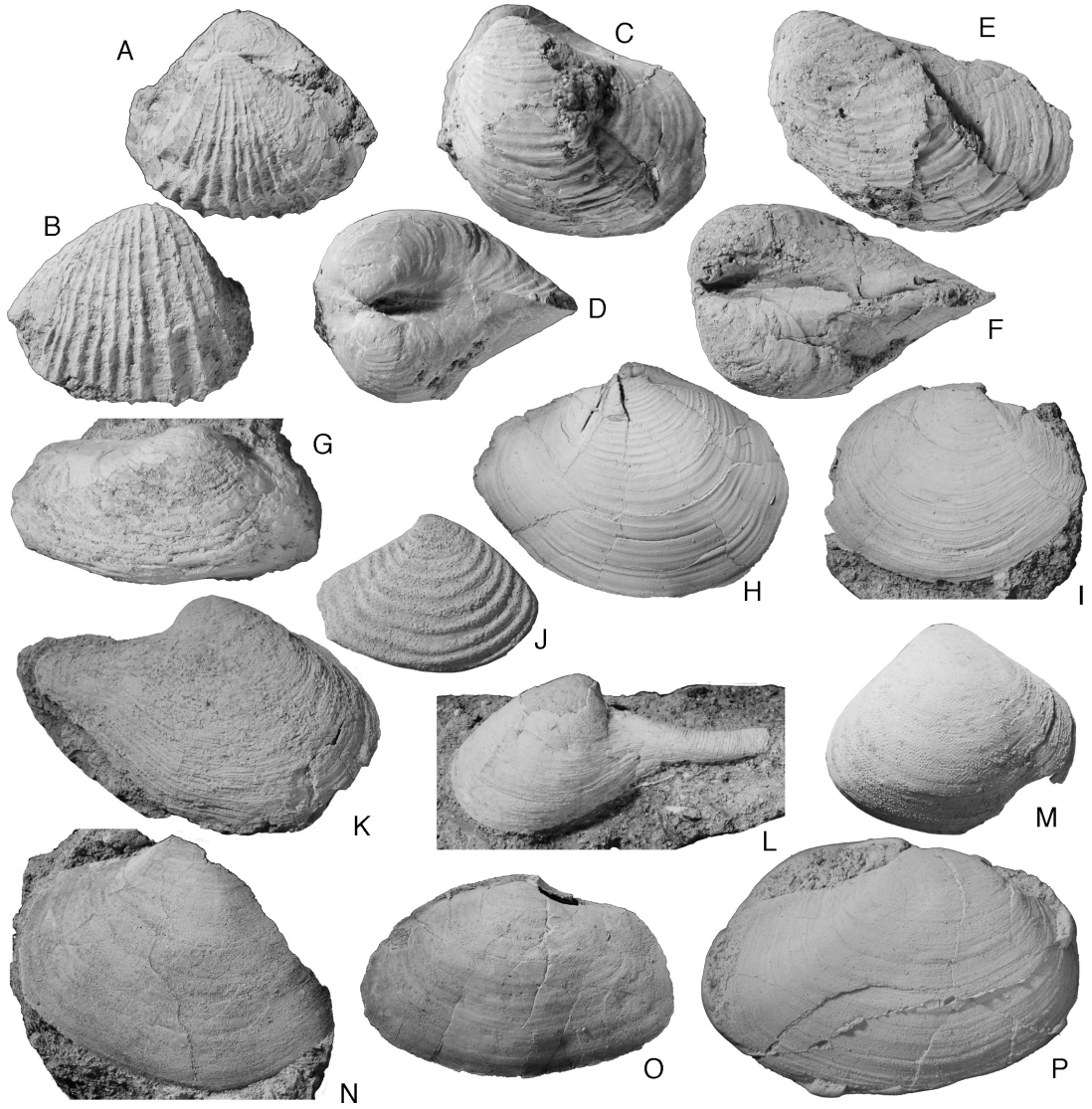


Fig. 30. **A, B**. *Panacca* sp. aff. *P. trigona* Sasaki and Okutani. CV, NMNS PM25189, 22.0×15.0+ mm, loc. Iwd-18, Negishi Fm. [A, left view: B, right view (×1.5)]. **C–F**. *Parilimya kawadai* (Omori) comb. nov. C, D: CV, NMNS PM25190, 36.0×31.0×25.7 mm, loc.Iwd-13U, Negishi Fm. [C, left view: D, dorsal view (×1)]. E, F: CV, NMNS PM25191, 40.4×32.0×26.4 mm, loc.Iwd-13U, Negishi Fm. [E, left view: F, dorsal view (×1)]. **G**. *Parilimya* sp. RV, NMNS PM25193, 39.0+×22.0+×9.8 mm, loc. Iwd-18, Negishi Fm. [exterior (×1)]. **H**. *Periploma mitsuganoense* Shibata. CV, NMNS PM25199, 28.6×21.6 mm, loc. Iwd-25, Shogunzawa Fm. [right internal mold (×1.5)]. **I**. *Periploma pulchellum* Hatai and Nisiyama. CV, NMNS PM25201, 22.7+×17.4 mm, loc. Iwd-22, Negishi Fm. [left view (×1.5)]. **J**. *Myadora ikebei* Habe. GMNH PI2254, 12.0×8.7 mm, loc. Tom-HN8, Itahana Fm. [exterior (×2.6)]. **K**. *Cuspidaria nobilis* (A. Adams). RV, NMNS PM25212, 31.7×21.6×8.1 mm, loc. Iwd-15, Negishi Fm. [exterior (×1.3)]. **L**. *Cuspidaria* sp. cf. *C. macrorhynchus* Smith. LV, NMNS PM25215, 21.3×11.0 mm, loc. Iwd-22, Negishi Fm. [exterior (×2)]. **M**. *Poromya flexuosa* Yokoyama. LV, GMNH PI2257, 18.2×15.5× 6.8 mm, loc. Tom-HN8, Itahana Fm. [exterior (×1.8)]. **N–P**. *Thracia hitosaoensis* Nomura. N: RV, IGUT 14331, 53.0+×42.4+ mm, loc. Kar-41, Kobana Fm. [internal mold (×0.8)]. O: CV, IGUT 14326, 51.6×33.6 mm, loc. Kar-41, Kobana Fm. [left internal mold (×0.8)]. P: RV, NMNS PM25194, 56.0×38.8+ mm, Kar-41, Kobana Fm. [exterior, rubber cast (×0.8)]

Pholadomya candida G. B. Sowerby, 1823 by subsequent designation) but to *Parilimya* Melvill and Standen, 1899 (type species: *Pholadomya* (*Parilimya*) *haddoni* Melvill and Standen, 1899 by monotypy) in lacking prominent radial ornaments. Coan (2000) synonymized *Nipponopanacca* Habe, 1977 (type species: *Pholadomya* (*Panacca*) *sakuraii* Habe, 1958 by original designation) with *Parilimya*, and I follow his opinion. Iwai (1959, 1965) and Amano *et al*. (1989) illustrated specimens of *Pholadomya kawadai* from the Pliocene of Aomori and Akita Prefectures, respectively. However, their specimens differ from the present species as the umbo is located one third of the length from the anterior end.

Occurrence.—Negishi Fm., loc. Iwd-13U.

Stratigraphic and geographic range.—This species was previously reported only from the Middle Miocene Kobana Formation, Tochigi Prefecture. I could not obtain any additional specimen of this species from the Kobana Formation in this study.

Parilimya sp.

(Fig. 30G)

Material.—One specimen (NMNS PM25193) form the Loc. Iwd-18.

Remarks.—This species is represented by a pair of valves consisting of a right valve missing the posterior end and a fragmentary left valve. The shell is moderate in size, nacreous, thin, and moderately inflated. The umbo is located at almost one fourth of the length from the anterior margin. The anterior margin is rounded, and the postero-dorsal margin is almost straight. The ventral margin is damaged. The shell possesses numerous irregular commarginal undulations, but without radial sculptures. The escutcheon and lunule are absent. Interior characters are unknown.

This unnamed species is most similar to *Parilimya kawadai* (Omori, 1952) in its shell size and mode of the exterior ornaments. However, the former is distinguishable from the latter in having the umbo located at about one quarter of the length from the anterior end and the finer irregular commarginal undulations.

Occurrence.—Negishi Fm., loc. Iwd-18.

Family Pandoridae Rafinesque, 1815
Genus ***Pandorella*** Conrad, 1863

Pandorella sp.

Material.—Two specimens (NMNS PM25194) from loc. Iwd-22.

Remarks.—Although the specimens examined are poorly preserved to allow their specific identification, they seem to be referable to *Pandorella* in its flat right valve and slightly inflated left valve divided into three parts by two radial sulci.

Occurrence.—Negishi Fm., locs. Iwd-14, 15, 22.

Family Myochamidae Bronn, 1862
Genus ***Myadora*** Gray, 1840

Myadora ikebei Habe, 1950

(Fig. 30J)

Myadora ikebei Habe, 1950, p. 30, pl. 4, fig. 17; Oyama, 1973, p. 119, pl. 57, figs. 2, 3, 7, 8; Habe, 1977, p. 307; Baba, 1990, p. 311, pl. 40, fig. 10 [contains synonymies].

Material.—One specimen (GMNH PI2254) from loc. Tom-HN8.

Remarks.—The shell is rather small (L 12.0 mm, H 8.7 mm) and elongate trapezoid in form. The beak is located at the mid-length. The exterior shell surface is sculptured with rough commarginal undulations. These characters agree well with those of *Myadora ikebei* from the Pleistocene Yabu Formation, Chiba Prefecture.

This species is similar to *Myadora suzuensis* Masuda, 1966 from the lower Middle Miocene Higashi-Innai Formation, Ishikawa Prefecture in general appearance, but is said to be distinguished in having a less-developed keel extending from the beak to the posterior end and regularly spaced coarse commarginal undulations.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species was previously reported only from the Pleistocene of central Honshu (Baba, 1990). The specimen from the Itahana Formation represents the oldest record of this species.

Family Thraciidae Stoliczka, 1870
Genus ***Thracia*** Blainville, 1824

Thracia hitosaoensis Nomura, 1935

(Fig. 30N–P)

Thracia hitosaoensis Nomura, 1935a, p. 107, pl. 7, fig. 7; Hatai, 1941, p. 115, pl. 8, figs. 9, 10, 11, 13; Otuka, 1941, pl. 1, fig. 5; Kamada, 1955, p. 99–100, pl. 1, figs. 3, 4.
Thracia kamayasikiensis Hatai, 1940, p. 123, pl. 1, fig. 2; Masuda and Takegawa, 1965, pl. 2, figs. 9, 10; Ogasawara and Yashima, 1981, p. 43–44, pl. 3, fig. 6; Amano, 1995, p. 145–146, pl. 1, figs 1a–2b.
Thracia kamayashikiensis [sic] Hatai: Kamada, 1955, p. 101–102, pl. 1, figs. 7–8; Kamada, 1962, p. 78, pl. 6, fig. 10.
Thracia kurosawaensis Hayasaka, 1957, p. 28–29, figs. 1a–c.

Material.—Thirty-two specimens (IGUT 14327–14331; NMNS PM15195–15197) from loc. Kar-41; 16 specimens (NMNS PM25198) from loc. Kar-40.

Remarks.—Conjoined mold specimens here assigned to *Thracia hitosaoensis* Nomura, 1935 occurs abundantly from the Kobana Formation at some localities. The shell is moderate in size (L<65 mm), moderate in convexity, and elongate oval to trapezioidal in form. The exterior shell surface is lacking conspicuous pustules and almost smooth except for growth lines.

Japanese Miocene species of the genus *Thracia* have been mainly distinguished by slight differences in shell outline, but their intraspecific variation is not well understood. The wide variation in shell form among the Kobana specimens suggest that the two Miocene species, *Thracia kamayasikiensis* Hatai, 1940 and *Thracia kurosawaensis* Hayasaka, 1957 are junior synonyms of *T. hitosaoensis*. *Thracia kakumana* Yokoyama, 1927, the most common species of *Thracia* in the Plio-Pleistocene of Japan, differs from this species in its larger shell size and in the presence of conspicuous pustules on the exterior surface. Taxonomic revision of Miocene *Thracia* in Japan is needed.

Occurrence.—Kobana Fm., locs. Kar-39, 40, 41; Negishi Fm., loc. Iwd-13U.

Stratigraphic and geographic range.—This species is reported to range from the lower Middle Miocene to Lower Pliocene of Honshu. The fossil occurrence of this species was given by Amano (1995) as *T. kamayasikiensis*.

Family Periplomatidae Dall, 1895
Genus ***Periploma*** Schumacher, 1817

Periploma mitsuganoense Araki, 1959

(Fig. 30H)

Periploma mitsuganoense Araki, 1959, p. 163, pl. 18, figs. 2a, b; Kurihara, 2000, p. 12, pl. 4, fig. 21 [contains synonymies].

Material.—Two specimens (GMNH PI2046, 2047) from loc. Tom-19; two specimens (NMNS PM25199, 25200) from loc. Iwd-25.

Occurrence.—Haratajino Fm., locs. Tom-2, 19; Haraichi Fm., loc. Tom-HN4; Shogunzawa Fm., locs. Iwd-24, 25, 27.

Periploma pulchellum Hatai and Nisiyama, 1949

(Fig. 30I)

Periploma pulchellum Hatai and Nisiyama, 1949, p. 90, pl. 23, figs. 17, 18; Kamada, 1962, p. 75, pl. 6, figs. 5–7.
Periploma (*Periploma*) *pulchella* Hatai and Nisiyama: Amano, 1983, p. 59–60, pl. 6, fig. 10.
Periploma pulchella Hatai and Nisiyama: Okamoto *et al*., 1990, pl. 11, figs. 39, 40; Noda, 1992, p. 95, figs. 7a, b, 11 [contains synonymies].

Material.—Three specimens (NMNS PM25201, 25202) from loc. Iwd-15.

Remarks.—The specimens assigned to *Periploma pulchellum* Hatai and Nisiyama, 1949 are characterized by their small shell (L＜30 mm) and narrowly arched ventral margin. This species differs from *Periploma mitsuganoense* Araki, 1959 by its smaller shell size and proportionally shorter shell outline and the absence of commarginal undulations.

Occurrence.—Negishi Fm., locs. Iwd-15, 16, 18, 22.

Stratigraphic and geographic range.—This species is reported to occur in the Oligocene to Upper Miocene of Honshu and Hokkaido (see Noda, 1992).

Family Verticordiidae Stoliczka, 1871
Genus ***Halicardia*** Dall, 1895

Remarks.—Several specimens of *Halicardia* were available for this study, and two species are recognized. Their description will be given after the detailed comparison with modern specimens.

Halicardia sp. A

Material.—One specimen (IGUT 14313) from loc. Kar-40; four specimens (NMNS PM15203) from loc. Iwd-13L; seven specimens (NMNS PM15204–15206) from loc. Iwd-15; one specimen (NMNS PM15207) from loc. Iwd-16; one specimen (NMNS PM15208) from loc. Iwd-18; one specimen (NMNS PM15209) from loc. Iwd-22; one specimen (NMNS PM15210) from loc. Iwd-23

Occurrences.—Kobana Fm., loc. Kar-40; Arakawa Fm., loc. Iwd-3G; Godo Fm., loc. Iwd-13L; Negishi Fm., locs. Iwd-15, 16, 18, 22, 23.

Halicardia sp. B

Material.—One specimen (NMNS PM15211) from loc. Iwd-13L.
Occurrence.—Godo Fm., loc. Iwd-13L.

Family Poromyidae Dall, 1886
Genus ***Poromya*** Forbes, 1844

Poromya flexuosa Yokoyama, 1922

(Fig. 30M)

Poromya flexuosa Yokoyama, 1922, p. 173, pl. 14, figs. 15, 16; Kuroda *et al*., 1971, p. 732 [Japanese part], p. 483 [English part], pl. 103, figs. 27, 28; Oyama, 1973, p. 120, pl. 57, figs. 20, 23; Shibata *in* Itoigawa *et al*., 1974, p. 109, pl. 35, figs. 1–3; Itoigawa *et al*., 1981, pl. 22, figs. 8a, b; Itoigawa *et al*., 1982, p. 117–118; Baba, 1990, p. 312, 313, pl. 40, fig. 15 [contains synonymies]; Okutani, 2000c, p. 1041, pl. 518, fig. 1.
Poromya yamaokana Nomura and Hatai, 1936, p. 133, pl. 15, fig. 2.

Material.—One specimen (GMNH PI2257) from loc. Tom-HN8.

Remarks.—This species is represented by a single, almost complete left valve. The shell is large (L 18.2 mm, H 15.5 mm, W 6.8 mm) for the genus and well inflated. The umbo is moderately elevated, slightly prosogyrate and located at the mid-length of the valve. The anterior end is evenly rounded, and the posterior end is subtruncate. The posterior slope sets off by a weak radial sulcus. The exterior surface is covered totally with minute pustules.

Although the shell size is rather large, the shell proportion of the specimen examined falls within the variation of the extant *Poromya flexuosa* Yokoyama, 1922 (e.g., Kuroda *et al*., 1971, pl. 103, fig. 27). *Poromya yamaokana* Nomura and Hatai, 1936 from the Tanagura Bed [=Kubota Formation] , Fukushima Prefecture, which was said to differ from *P. flexuosa* in the absence of the posterior fold, is regarded as a junior synonym of *P. flexuosa* because there is a variation in degree of the development of radial sulcus in *P. flexuosa*.

Occurrence.—Itahana Fm., loc. Tom-HN8.

Stratigraphic and geographic range.—This species is reported to range from the lower Middle Miocene to Holocene. Modern distribution is reported at depths of 30 to 300 m, Kyushu to southern Hokkaido (Okutani, 2000c).

Family Cuspidariidae Dall, 1886
Genus ***Cuspidaria*** Nardo, 1840

Cuspidaria nobilis (A. Adams, 1864)

(Fig. 30K)

Neaera nobilis A. Adams, 1864, p. 207; Kuroda, 1948a, p. 15–16, pl. 1, fig. 5.
Cuspidaria nobilis (A. Adams): Kuroda *et al*., 1971, p. 734 [Japanese part], p. 484 [English part], pl. 103, fig. 16; Okutani *et al*., 1989, p. 179, 2 figs.; Noda *et al*., 1993, p. 168, figs. 22.1, 22.2 [contains synonymies].
Cuspidaria nobilis nobilis (A. Adams): Okutani, 2000c, p. 1043, pl. 519, fig. 1.

Material.—Two specimens (NMNS PM25212, 25213) from loc. Iwd-15; two specimens (NMNS PM15214) from loc. Iwd-18.

Remarks.—The specimens assigned here to *Cuspidaria nobilis* (A. Adams, 1864) are characterized by their large size (L<40 mm), rounded disc and broad, short posterior projection.

Occurrence.—Negishi Fm., locs. Iwd-15, 18.

Stratigraphic and geographic range.—This species was previously reported to range from the Pliocene to Holocene. The specimens from the Negishi Formation represent the oldest fossil record of this species. This species is currently known to occur at depths of 50 to 200 m, from off Boso Peninsula to off Kyushu (Okutani, 2000c).

Cuspidaria sp. cf. ***C. macrorhyncha*** Smith, 1895

(Fig. 30L)

Compare.—
Cuspidaria macrorhyncha Smith, 1895, p. 12, pl. 2, figs. 5, 5a; Okutani, 2000c, p. 1045, pl. 519, fig. 7.

Material.—Four specimens (MMNS PM25215, 25216) from loc. Iwd-22.

Remarks.—The specimens examined are characterized by their moderate shell size (L<30 mm) and almost straight, long and narrow posterior projection. The exterior surface is sculptured with dense commarginal growth lines. These characters agree with those of *Cuspidaria macrorhyncha* Smith, 1895, but their incompleteness and deformation do not allow their positive assignment.

Occurrence.—Godo Fm., loc. Iwd-13L; Negishi Fm., locs. Iwd-13U, 15, 22, 23.

Stratigraphic and geographic range.—*C. macrorhyncha* is currently known to occur at depths of 50 to 1170 m, off Sanriku to Indonesia (Okutani, 2000c). This species has never been reported as fossil.

Cuspidaria sp.

Cuspidaria sp.: Kurihara, 1999, fig. 26.24.

Material.—One specimen (IGUT 11844) from loc. Iwd-1.

Occurrence.—Arakawa Fm., loc. Iwd-1.

Genus ***Myonera*** Dall, 1886

Myonera osawanoensis (Tsuda, 1959)

Cuspidaria osawanoensis Tsuda, 1959, p. 73, pl. 2, figs. 2a, b.
Myonera osawanoensis (Tsuda): Kurihara, 1999, p. 232, figs. 6.25–6.27 [contains synonymies]; Kurihara, 2000, p. 12, pl. 4, fig. 15.

Material.—One specimen (GMNH PI2048) from loc. Tom-1; two specimens (IGUT 11845-1, 2) from loc. Iwd-1; one specimen (IGUT 11845-3) from loc. Iwd-2.

Occurrence: Haratajino Fm., loc. Tom-1; Arakawa Fm., locs. Iwd-1, 2.

Genus ***Cardiomya*** A. Adams, 1864
Subgenus ***Cardiomya*** s. s.

Cardiomya* (*Cardiomya*) *mitsuganoensis Shibata, 1970

Cardiomya mitsuganoensis Shibata, 1970, p. 67, pl. 2, figs. 9, 10; Kurihara, 1999, fig. 6.28, 6.29.

Material.—Two specimens (IGUT 11854-1, 2) from loc. Iwd-2.

Occurrence.—Arakawa Fm., loc. Iwd-2.

***Cardiomya* (*Cardiomya*)** sp.

Material.—Two specimens (NMNS PM25217) from loc. Tom-45a.

Remarks.—The specimens examined are characterized by their small shell size (L＜14 mm) and the presence of about 15 radial threads on the disc. Specific identification of the specimens is difficult due to the incomplete preservation.

Occurrence.—Itahana Fm., loc. Tom-45a.

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