A new Miocene Yabepecten (Bivalvia: Pectinidae) from the Hongô Formation in northeast Japan

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Abstract. Yabepecten ogasawarae sp. nov. is proposed from the Hongô Formation in Yamagata Prefecture, northeastern Honshû, Japan. Its occurrence is inferred to be of early late to middle late Miocene age, which makes Y. ogasawarae sp. nov. the oldest Yabepecten in the northwestern Pacific. Yabepecten was derived from Patinopecten in the northeastern Pacific, and migrated into the northwestern Pacific by the early late Miocene. From the early late Miocene onward, Yabepecten followed different evolutionary histories on both sides of the North Pacific. Yabepecten became extinct in the northeastern Pacific by the end of the early late Miocene. However, Yabepecten flourished in the northwestern Pacific from the late Pliocene to early Pleistocene, only becoming extinct at the beginning of the middle Pleistocene, along with many other species of the Omma-Manganji Fauna.

Key words: evolutionary history, late Miocene, northwestern Pacific, Yabepecten, Yabepecten ogasawarae sp. nov.

Introduction

Yabepecten is a pectinid genus typified by Pecten tokunagai Yokoyama, 1911, which was originally described from the lower Pleistocene Koshih Formation on the Miura Peninsula, Kanagawa Prefecture, central Honshû, Japan (Masuda, 1963). The type species is peculiar for northwestern Pacific pectinids in having auricular crura with distal denticles. This character is common in Patinopecten Dall, 1898 (Patinopectininae sensu Kafanov, 1986a, b) in the northeastern Pacific, but is entirely absent in Mizuhopecten Masuda, 1963, and related genera (Fortipectininae sensu Masuda, 1963, and Kafanov, 1986a, b) in the northwestern Pacific.

Yabepecten tokunagai has mainly been found in upper lower Pliocene to lower Pleistocene deposits from central Honshû to southern Hokkaidô (e.g., Masuda and Ogasawara, 1981; Uozumi et al., 1986a; Matsui, 1990; Ogasawara, 1996). The oldest record of Yabepecten in the northwestern Pacific was from uppermost Miocene or lowermost Pliocene deposits on Hokkaidô (Uozumi et al., 1986a). However, Yabepecten condoni (Hertlein, 1925) occurs in the upper Miocene Montesano Formation of Washington, U.S.A. (Masuda and Addicott, 1970), where its oldest occurrence has been dated as of early late Miocene age, based on diatoms and magnetostratigraphic data (Barron, 1981; Prothero and Lau, 2001). This occurrence is much earlier than in the northwestern Pacific. The origin and migration of Yabepecten have been discussed from the viewpoints of chronologic and geographic distribution patterns (e.g., Masuda and Addicott, 1970; Masuda, 1986; Uozumi et al., 1986a; Amano and Karasawa, 1988).

In the course of examining collections in the Museum of Natural History, Tohoku University (abbreviated as IGPS), I found a new late Miocene Yabepecten from northeastern Japan (Figure 1). This is the first record of Yabepecten from lower upper or middle upper Miocene deposits in the northwestern Pacific. I propose Yabepecten ogasawarae sp. nov. and discuss its paleobiogeographic implications.

Systematic description

The terminology used herein for cardinal properties is principally from Waller (1991) (Figure 2). Right and left valves are abbreviated as RV and LV, respectively. A new term, inner dorsal flexure (idf), refers to a rounded radial flexure on the inner side of both antero- and posterodorsal parts of the disc (Figure 2.1b, 2.2b).
Family Pectinidae Wilkes, 1810
Subfamily Chlamydiinae von Teppener, 1922
Tribe Chlamydini von Teppener, 1922
Genus Yabepecten Masuda, 1963

Type species.—Pecten tokunagai Yokoyama, 1911, by original designation. Koshiba Formation, early Pleistocene.

Emended diagnosis.—Chlamydid with a circular, compressed, rather thin shell; RV generally more inflated than LV; RV radial costae low, flat-topped or rounded, irregular, broader or narrower than interspaces; LV concave or weakly inflated, sculptured by very fine to fine, low radial costae and strong shagreen microsculpture; LV generally lacking costae in interspaces; auricles rather small; byssal notch very shallow; resilifer small; auricular crura distinct, with a denticle on distal end; dorsal teeth strong; inner dorsal flexures distinct on both RV and LV.

Figure 1. Location of type locality (after Ogasawara et al., 1985; black star).

Discussion.—The taxonomic status of Yabepecten is controversial. Masuda (1963) considered this genus phylogenetically close to Patinopecten and Pecten Müller, 1776 rather than to Mizuhopecten and related genera (Fortipecten Yabe and Hatai, 1940, Masudapecten Akiyama, 1962, Kotorpecten Masuda, 1962, and Nipponpecten Masuda, 1962) in the northwest Pacific, because the auricular crura with denticles on the distal end are shared by Yabepecten, Patinopecten and Pecten. Based on this difference, Masuda (1963) referred Yabepecten and Patinopecten to the subfamily Pectininae, and the above northwest Pacific genera except for Yabepecten to the Fortipectinidae. Masuda (1963) stated that the five genera in the Fortipectininae are distinguished from Patinopecten in having rounded radial costae in the RV, a very shallow byssal notch and larger auricles in addition to the absence of auricular crura with denticles. In contrast, Hertlein (1969) regarded Yabepecten as a member of the Pecten (Patinopecten) subgroup of the Pecten group and used it as a subgenus of Pecten. He5questionably considered the northwestern Pacific Masudapecten, Kotorpecten and Mizuhopecten as synonyms of Patinopecten. Habe (1977) revised Hertlein’s (1969) classification and treated Mizuhopecten, Yabepecten and Kotorpecten as subgenera of Patinopecten, and grouped them into the single subfamily Patinopectininae “Masuda, 1962” [sic] (see Kafanov, 1986a, b for discussion on the exact author).

Kafanov (1986a, b) revised Masuda’s (1963) classification system and referred the northwestern Pacific genera Mizuhopecten, Fortipecten, Masudapecten, Kotorpecten and Nipponpecten to the subfamily Fortipectininae, as done by Masuda (1963), and the northeastern Pacific genus Patinopecten and its subgenus [Patinopecten s.s., Litupecten MacNeil, 1961, and “split-ribbed” Patinopecten (=Blanckenhornia von Teppener, 1922)], and tentatively the genus Vertipecten Grant and Gale, 1931, to the subfamily Pectininae, based on the morphological differences and inferred independent evolutionary histories since the early Miocene. Kafanov (1986a, b) considered Yabepecten referable to neither Patinopectininae nor Fortipectininae.

Waller (1991, 1993) proposed a new classification system for Pectinidae primarily on the basis of external microsculpture and cardinal properties rather than external macrosculpture. He pointed out that the external shell microsculpture and internal shell characters, including the cardinal structure of Mizuhopecten and Patinopecten, are coincident with those of the Chlamys group rather than the Pecten group. Waller (1991) observed that auricular crura, with or without denticles on the distal end, appear repeatedly in many clades of Pectinoidea, and therefore cannot be used as a uniquely derived character for distinguishing Patinopecten from Mizuhopecten. He concluded that Mizuhopecten and Patinopecten are members of the subfamily Chlamydiinae, and considered that these two genera may be referable to distinct subtribes of a single tribe. Following Waller’s (1991) opinion, Kafanov and Lutaenko (1998) reduced the rank of the subfamily Fortipectininae to a tribe in the subfamily Chlamydiinae, and referred the extant genera Patinopecten and Mizuhopecten to the tribe Fortipectinitini.

Recently, Matsumoto and Hayami (2000) strongly bolstered Waller’s (1991, 1993) classification system, based on molecular phylogenetic analysis of extant pectinids using mitochondrial cytochrome c oxidase subunit 1. Their results include Mizuhopecten in the same clade as Chlamys [Röding, 1798], Swiftpecten Hertlein, 1936 and Azumapecten Habe, 1977 (=Leochlamys MacNeil, 1967). However, the phylogenetic relationship between this group of genera and Patinopecten remains obscure.

In my opinion, Yabepecten is a member of the tribe Chlamydiini, as are Patinopecten and Mizuhopecten, based on the presence of shagreen microsculpture on the LV, and on the cardinal properties. The auricular crura with denticles on the distal end, which were considered to be a significant character of Pectinidae by Masuda (1963, 1971), are not useful for subfamily-level classification, as noted by Waller (1991). However, this feature is useful for separating the northeastern Pacific Patinopecten and the northwestern Pacific Mizuhopecten, Fortipecten, Masudapecten, Kotorpecten and Nipponpecten, given the morphological differences that have resulted from their separate evolutionary histories on either side of the North Pacific since the early Miocene (Masuda, 1963, 1971; Kafanov, 1986a, b). Consequently, I consider that Yabepecten was derived from Patinopecten and migrated westward into the northwestern Pacific by the early late Miocene.

Masudapecten, based on Patinopecten (Masudapecten) masudai Akiyama, 1962, from the lower middle Miocene Sugota Formation in Akita Prefecture, northeastern Japan, closely resembles Yabepecten. Similarities include having the LV sculptured by stringy radial costae and shagreen microsculpture, at least on immature shells. However, Masudapecten lacks auricular crura with denticles, and has less developed inner dorsal flexures. In addition, this genus has several striated threads in the interspaces of radial costae on the LV, and finely sulcated radial costae on the RV. Patinopecten differs from Yabepecten in having stouter LV radial costae, very high and squarish RV radial costae, larger auricles and a deeper byssal notch.

Yabepecten ogasawarae sp. nov.

Figures 2, 3, 4.2, 4.4, 4.6a-b

**Mizuhopecten parablebejus murataensis** Masuda and Takegawa.

Ogasawara et al., 1985, p. 31, pl. 2, figs. 5, 7, pl. 3, figs. 1, 5. [not of Masuda and Takegawa, 1965].

**Type specimens.**—Holotype: IGPS 98911–1; paratypes: IGPS 98911–2, 98911–3, 98911–4 and 98911–5. These are specimens of *Mizuhopecten parablebejus murataensis* figured by Ogasawara et al. (1985). There should be another figured specimen in the IGPS collection (Ogasawara et al., 1985, pl. 2, fig. 5: IGPS 98911), but it was not found when I visited the Natural History Museum, Tohoku University.

**Type locality, formation and age.**—“Bed of the Sagae River, about 250 m downstream of ‘Uwano O-hashii’ [‘Uwano big bridge’] over the Sagae River and about 500 m south-southwest of the hamlet of Uwano, Sagae City, Yamagata Prefecture” (Ogasawara et al., 1985, p. 7). Öya Tuffaceous Sandstone Member of the Hongō Formation, late Miocene.

**Diagnosis.**—*Yabezpecten* with moderate-size, moderately thick shell; LV rather inflated; auricles small; byssal fasciole weakly flexed, rather broad; RV radial costae 18, low, broad, flat-topped, round-edged; LV radial costae 18–20, fine, tending to become weakly bi- or tripartite with shell growth; dorsal and inner dorsal teeth strong.

**Description.**—Shell moderate in size, moderately thick, circular, slightly longer than high, compressed, nearly equilateral except for auricles; apical angle about 120°; both antero- and postero-dorsal margins gape.

RV rather inflated compared to LV; radial costae 18, low, flat-topped, rather irregular, indistinctly defined from interspaces, rarely dichotomous owing to a very shallow median groove; interspaces shallow, somewhat narrower than costae; commarginal growth lines rather distinct, fine to coarse, irregular; auricles small; byssal fasciole broad, very weakly flexed, sculptured by fine to coarse, irregular growth lines; byssal notch very shallow; hinge line very bluntly v-shaped; resilifer moderate in size, moderately concave; resilifer teeth rather strong, with anterior tooth stronger than posterior tooth; dorsal teeth strong; anterior auricular crus indistinct; posterior auricular crus weakly elevated; inner dorsal flexures distinct; thin, foliated calcite layer inside of pallial line; adductor muscle scar indistinct except for dorsal part, reentered by foliated calcite layer; internal disc very weakly folded in concert with radial costae.

LV weakly inflated; radial costae 18–20, fine, tending to become weakly bi- or tripartite with shell growth; faint costae rarely present in interspaces; shagreen microsculpture on entire external shell; commarginal growth lines indistinct; interspace of costae shallow, slightly round-bottomed; auricles small, sculptured by irregular, rather widely spaced growth lines and fine, low, radial costae; hinge line nearly straight; resilifer same as that of RV; sockets of resilifer teeth distinct, especially the anterior one; infradorsal teeth strong; supradorsal teeth very narrow; sockets of dorsal teeth rather deeply concave; anterior auricular crus distinct, with a low distal denticle; posterior auricular crus indistinct, but with a distal denticle; dorsal flexures distinct; foliated calcite layer inside of pallial line, very thin; other internal features same as RV.

**Etymology.**—This species is named in honor of Prof. Kenshiro Ogasawara of the Institute of Geoscience, the University of Tsukuba.

**Discussion.**—The type specimens of this new species were once referred to as *Mizuhopecten parablebejus murataensis* Masuda and Takegawa, 1965, which was originally described from the upper Miocene Fukuda Formation in Miyagi Prefecture, northeastern Japan (Ogasawara et al., 1985). The most significant difference between the two taxa is the mode of the auricular crura. The present new species has auricular crura with rather distinct denticles on the distal end, whereas *M. parablebejus murataensis* has less developed crura that lack denticles, as seen in other members of *Mizuhopecten*. In addition, *M. parablebejus murataensis* has much larger auricles, a more inflated RV with more distinct radial costae, and an LV with stouter radial costae and less developed shagreen microsculpture (Fig. 4.2, 4.4, 4.6a–c). The other significant difference is the mode of development of the inner dorsal flexures. The flexures are well developed in the LV of the Hongō specimens, whereas they are indistinct in *M. parablebejus murataensis*. Taking account of these characters, the Hongō specimens are assigned to *Yabezpecten* rather than *Mizuhopecten*.

The specimens illustrated by Ogasawara (1983) as *M. parablebejus murataensis* from the Hashigami Sandstone Member of the Hongō Formation is probably referable to the present new species, although a definite assignment cannot be made because the specimens are not preserved well.

The present new species closely resembles *Yabezpecten condoni* (Hertlein, 1925), from the lower upper Miocene Montesano Formation of Washington, in having a weakly inflated LV. However, it differs from that species by having a larger shell with smaller auricles and stronger shagreen microsculpture. *Y. ogasawai* sp. nov. is also similar to the “smooth form” of *Patinopecten* (Patinopecten...
Table 1. Measurements of Yabepecten ogasawarai sp. nov.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Length</th>
<th>Height</th>
<th>Convexity</th>
<th>Umbonal angle</th>
<th>Number of radial costae</th>
<th>Valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGPS 98911-1 (holotype)</td>
<td>82.9 mm</td>
<td>86.1 mm+</td>
<td>8.6 mm</td>
<td>120°</td>
<td>18 Right</td>
<td></td>
</tr>
<tr>
<td>IGPS 98911-2 (paratype)</td>
<td>80.7 mm</td>
<td>82.5 mm</td>
<td>8.6 mm</td>
<td>122°</td>
<td>18 Left</td>
<td></td>
</tr>
<tr>
<td>IGPS 98911-3 (paratype)</td>
<td>45.1 mm</td>
<td>45.6 mm</td>
<td>4.1 mm</td>
<td>123°</td>
<td>20 Left</td>
<td></td>
</tr>
<tr>
<td>IGPS 98911-4 (paratype)</td>
<td>36.1 mm+</td>
<td>39.0 mm</td>
<td>3.6 mm</td>
<td>112°</td>
<td>19 Left</td>
<td></td>
</tr>
<tr>
<td>IGPS 98911-5 (paratype)</td>
<td>30.4 mm</td>
<td>31.3 mm</td>
<td>4.1 mm</td>
<td>119°</td>
<td>19 Left</td>
<td></td>
</tr>
</tbody>
</table>

Evolutionary history of Yabepecten

The oldest known species of Yabepecten is Y. condoni (Hertlein) from the upper Miocene Montesano Formation of Washington along the northeastern Pacific margin (Loc. 22 in Figure 5). This species has been cited as an index fossil for the Graysan Stage (Addicott, 1976, 1977, 1984). According to Barron (1981a) the diatom assemblages of the Montesano Formation are referred to subzone b of the XV-XVI to XIII-XIV zones of Barron (1976). These zones correspond to Subzone d of the Denticulopsis husteedii-Denticulopsis lauta Zone and Subzone a of the Denticulopsis husteedii Zone of Barron (1981b), which implies an early late Miocene age. Prothero and Lau (2001) recently examined the magnetostratigraphy of the Montesano Formation. Although their recognition of the lower limit of the type Graysan Stage differs from Addicott (1976), this stage can be correlated with chron C4Ar2r to C4Ar1r (9.584–9.025Ma: Cande and Kent, 1995; Berggren et al., 1995b). Yabepecten in the northeastern Pacific is known only in the Graysan Stage (Addicott, 1976, 1977, 1984) and is considered to have become extinct by the end of the early late Miocene.

In contrast, the oldest species of Yabepecten in the northwestern Pacific is Y. ogasawarai sp. nov. from the Ōya Tuffaceous Sandstone Member of the Hongō Formation in northeastern Honshū, Japan (Loc. 10 in Figure 5). Diatom assemblages from this member indicate that its horizon is somewhere between the Denticulopsis katayamae and the lowest part of Rouxia californica Zones of Akiba (1986) (Akiba, 1983; Takahashi et al., 1986; Manuyama, 1993; Kanamori et al., 1996). According to Motoyama and Manuyama (1998) and Yanagisawa and Akiba (1998), these zones range from 9.2 or 9.1 to 7.4 or 7.3 Ma, following the magnetostratigraphy of Cande and Kent (1995) and Berggren et al. (1995b). This age is slightly younger than
is from the uppermost Miocene–lower Pliocene Atsuga Formation of Hokkaidō (Loc. 2 in Figure 5). Uozumi et al. (1986a) cited and figured Yabepecten cf. condoni (Hertlein) from this formation, and believed that the Atsuga specimens are much more similar morphologically to Y. condoni than to Y. tokunagai. However, *Y. tokunagai* exhibits a wide range of variation in the height and width of RV radial costae and LV convexity (e.g., Amano and Karasawa, 1988). Consequently, I consider that *Y. cf. condoni* of Uozumi et al. (1986a) is included within the intraspecific variation of *Y. tokunagai*. A latest Miocene to earliest Pliocene age for the Atsuga Formation is indicated by radiometric and diatom data (Uozumi et al., 1986b; Sagayama et al., 1992). Although Amano and Karasawa (1988) inferred that *Y. tokunagai* was derived from *Y. condoni*, the occurrence of *Y. ogasawarai* sp. nov. from upper Miocene strata of northeastern Japan implies that this species is more directly ancestral to *Y. tokunagai*.

There have been only a few records of *Yabepecten tokunagai* from lower Pliocene deposits, one of them being in the Arakurayama Pyroclastic Member of the Shigarami Formation in central Japan (Amano and Karasawa, 1988; Loc. 14 in Figure 5). Amano and Karasawa (1993) reported fission-track ages of 4.6 ± 0.2 and 4.7 ± 0.2 Ma (error: ±0.5), indicating an early Pliocene age for this member. Tsuchi and Ibaraki (1988) referred the Ogikubo Sandstone and Siltstone Member of the Shigarami Formation, which overlies the Arakurayama Pyroclastic Member, to planktonic foraminiferal zone N21 of Blow (1969), of late Pliocene age (3.35–2.0Ma: Berggren et al., 1995a).

Another early Pliocene record of *Y. tokunagai* may be from the Nakawatari Formation in Yamagata Prefecture, northeastern Honshū (Loc. 9 in Figure 5; Ogasawara et al., 1984). However, this formation contains few planktonic microfossils (Martynova, 1998; Aita et al., 1999), and age estimates based on biostratigraphic and radiometric data are not in agreement (Sato, 1986; Nagasawa et al., 1998, 1999), so further chronostratigraphic study is needed.

Occurrences of *Y. tokunagai* from the “upper Miocene to lower Pliocene” Okurglovskaya Formation on Paramushir Island in the Kurile Islands, northwestern Pacific (Zhikova et al. 1972) described as *Mizupecten cf. subyessoensis* (Yokoyama); Masuda, 1986; Amano and Karasawa, 1988; Loc. 20 in Figure 5), may be as old as those from the Shigarami and Nakawatari Formations. However, the precise geological age of the Okurglovskaya Formation is unknown, since there are no accompanying radiometric data or planktonic microfossils.

*Yabepecten tokunagai* flourished in southern Hokkaidō and the Sea of Japan side of central and northeast Honshū during the late Pliocene and early Pleistocene, as noted by many workers (Masuda and Ogasawara, 1981; Masuda, 1986; Uozumi et al., 1986a; Amano and Karasawa, 1988;

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**Figure 5.** Distribution of *Yabepecten*. A. Records from North Pacific. Area shown in Figure 5.B is also indicated. B. Records from Japan. See appendix for data sources.
Figure 5). These occurrences were in a mild- to cold-temperate marine climate somewhat colder than today’s (Ogasawara, 1994; Amano, 1994). It subsequently became extinct by the beginning of the middle Pleistocene, along with many other taxa in the Omma-Manganji Fauna.

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Appendix. Distribution of Yabepecten

Locality numbers are the same as in Figure 5.

Comment 1.—Uozumi et al. (1986a, fig. 2) cited the occurrence of Y. tokunagaii in the Plio-Pleistocene Kakegawa Formation [sic = Kakegawa Group] of central Japan. Nobuhara (1993) also reported this species in the upper Pleistocene–lower Pleistocene Ukari Formation of the Kakegawa Group. These records are excluded from Figure 5, because the occurrences are unverified due to the lack of figured specimens. If this record were true, it would be the only record from the late Pliocene-early Pleistocene subtropical realm.

Comment 2.—Pecten (Masuopecten) plebejus of Kubota (1950, p. 13–14, pl. 9, fig. 61) in the Setana Formation, Yabepecten tokunagaii of Iwai (1965, p. 30–31, pl. 15, fig. 14) in the Daishaka Formation, and Yabepecten tokunagaii of Shimamoto and Koike (1986, p. 36–37, pl. 5, fig. 12) in the Tentokuji Formation, are referable to Mizuopecten yessensis (Jay, 1857) or its subspecies, as noted by Masuda and Noda (1976), Takayasu et al. (1986) and Amano and Karasawa (1988).