

A new Miocene *Tindaria* (Bivalvia: Tindariidae) from central Honshu, Japan

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ABSTRACT

A new species of tindariid bivalve, *Tindaria hamuroi* **new species**, is described from the upper lower Miocene Higashibessho Formation in central Honshu, Japan which was deposited in lower sublittoral to upper bathyal settings. This is the first case of the fossil occurrence of an elongate ovate shell-type *Tindaria*. Among the fossil and extant species of *Tindaria*, *Tindaria hamuroi* **new species** is the only species from the Japan Sea side of Japan. Other than *Tindaria*, the nucinellid *Nucinella*, the malletiid *Malletia*, the mytilid *Bathymodiolus* (*s. l.*), the cuspidariid *Myonera*, and the vesicomysids *Pliocardia* and *Calyptogena* became extinct in the Japan Sea.

Additional Keywords: Higashibessho Formation, Japan Sea, paleobathymetry, Protobranchia

INTRODUCTION

The genus *Tindaria* was proposed by Bellardi (1875), based on the “Pliocene” [= Miocene] species *Tindaria arata* Bellardi, 1875 from northwestern Italy. Extant members of this genus are cosmopolitan deep-water dwellers ranging from 250 m to 6000 m in depth (Sanders and Allen, 1977; Salas, 1996; Xu, 1999; Kurozumi *et al.*, 2017). Twenty-six extant species are accepted by MolluscaBase (2021).

Coan *et al.* (2000), Coan and Valentich-Scott (2012) and Valentich-Scott *et al.* (2020) stated the genus dated to the Pliocene and expected much older records. However, the type species, *T. arata* itself dated back to the Messinian (late Miocene) as noted by Merlino (2007). A total of nine fossil taxa including two doubtful ones and two subspecies are known mainly from the Miocene and Pliocene in Europe, northwestern America and Japan (Table 1; Kurihara, 1999; Koskeridou *et al.*, 2019).

The oldest species of this genus is *Tindaria paleocenica* Amano and Jenkins, 2017 from the Paleocene Katsuhira Formation in eastern Hokkaido, northern Japan. An inner mold of *Tindaria*? sp. was illustrated

by Kurihara (1999) from the lower middle Miocene Arakawa Formation in Saitama Prefecture, central Honshu. Moreover, two specimens of *Tindaria* sp. were listed from the upper lower Miocene Higashibessho Formation in Toyama Prefecture, central Honshu by Amano *et al.* (2004).

As a result of our examination of the above Higashibessho specimens, we have determined that they are distinguished from all other fossil and extant species. Thus, we describe the specimens as a new species and discuss its evolutionary significance.

MATERIALS AND METHODS

Two specimens were recovered from mudstone of the lower part of Higashibessho Formation at Shimosasahara, Toyama City, central Honshu (see Amano *et al.*, 2004: figure 1). Based on diatom assemblages, the lower part of this Formation was assigned to the NPD3A zone (16.6–17.0 Ma; Yanagisawa and Akiba, 1998; Yanagisawa and Watanabe, 2017) by Yanagisawa (1999). Nakajima *et al.* (2019) dated the Yamadanaka Tuff just below the Higashibessho Formation to 16.6 and 16.4 by U-Pb and Fission track methods. From these data, the Higashibessho Formation at Shimosasahara can be assigned to the upper lower Miocene (Burdigalian).

Based on benthic foraminifers, the Higashibessho Formation was deposited in the middle to upper bathyal zone (Hasegawa and Takahashi, 1992). Molluscan and ostracod assemblages from the formation suggest an upper bathyal to lower sublittoral depth (Shimizu *et al.*, 2000; Amano *et al.*, 2004, Ozawa, 2016).

For morphological examination, we acquired scanning electron microscopy (SEM) images using a JEOL-5310 instrument (JEOL, Tokyo) at National Museum of Nature and Science, Tokyo (NMNS, Tsukuba, Ibaraki) with the standard technique following sputter coating with gold/palladium. Both specimens, including a silicone rubber replica of the right valve of the holotype, are housed in the Department of Geology and Paleontology, NMNS (NMNS PM 65153, PM 65154).

Table 1. List of fossil species of *Tindaria*.

Species	Age	District	Reference
<i>Tindaria paleocenica</i> Amano and Jenkins, 2017	Paleocene	Hokkaido, Japan	Amano and Jenkins (2017)
<i>T.</i> ? sp.	Oligocene	Washington, USA	Kiel (2006)
<i>T.</i> ? sp.	early middle Miocene	Honshu, Japan	Kurihara (1999)
<i>T. arata</i> Bellardi, 1875	middle ~ late Miocene	Northwest Italy	Bellardi (1875), Merlino (2007)
<i>T. arata subcytherea</i> Sacco, 1898	middle Miocene	Northwest Italy	Sacco (1898), Koskeridou <i>et al.</i> (2019)
<i>T. inopinata</i> Cossman and Peyrot, 1912	late Miocene	France	Cossman and Peyrot (1912)
<i>T. kretensis</i> Koskeridou, La Perna and Giamali, 2019	early Pliocene	Crete, Greece	Koskeridou <i>et al.</i> (2019)
<i>T. (T.)</i> sp.	late Pliocene	Jamaica	Woodring (1925), Donovan (1998)
<i>T. solida</i> Seguenza, 1877	Plio-Pleistocene	Southern Italy	Seguenza (1877)
<i>T. solida minor</i> Seguenza, 1879	Plio-Pleistocene	Southern Italy	Seguenza (1879)

SYSTEMATIC DESCRIPTION

Family Tindariidae Verrill and Bush, 1897

Genus *Tindaria* Bellardi, 1875

Type Species: *Tindaria arata* Bellardi, 1875 by original designation

***Tindaria hamuroi* new species** (Figures 1–7)

Diagnosis: Small and elongate species of *Tindaria* with well inflated umbo. Umbo located at anterior one-third of shell length. Surface sculptured by fine commarginal ribs.

Description: Shell medium for genus, to 7.6 mm long, rather thin, elongate ovate ($H/L = 0.79$ for holotype, 0.72 for paratype) with porcellanous inner layer, well inflated ($W/L = 0.59$ for holotype, 0.57 for paratype), equivalve, and inequilateral. Prodissoconch smooth, attaining about 300 μm in length. Antero-dorsal margin straight, continuing to semi-circular anterior margin; ventral margin broadly rounded; posterior end narrowly rounded or subtruncated, continuing to straight postero-dorsal margin. Umbo prominent, inflated, prosogyrate, located at anterior third of shell length ($AL/L = 0.34$ for holotype, 0.31 for paratype). Surface sculptured with many fine, distinct commarginal ribs. Hinge plate of left valve narrow, with two series of small teeth; 13 anterior teeth; 20 posterior teeth; no resilium or interruption. Posterior adductor muscle scar of right valve small, subovate-rhomboid. Pallial line entire, rather thick.

Holotype: A specimen that was originally conjoined; intact left valve (NMNS PM 65153a), length 7.6 mm, height 6.0 mm, and an outer mold of right valve preserved with fragments of the valve and a silicone rubber replica of the mold (NMNS PM 65153b); from the type locality.

Paratype: A conjoined specimen comprising both valves (NMNS PM 65154), length 5.8 mm, height 4.2 mm, width 3.3 mm; from the type locality.

Remarks: No fossil species resembles *Tindaria hamuroi* new species. It is most similar to the Recent Northwest

American species *Tindaria kennerlyi* Dall, 1897 in having an elongate ovate shell with inflated umbo. However, ***Tindaria hamuroi* new species** differs from *T. kennerlyi* by its smaller shell (10 mm long in *T. kennerlyi*; Coan *et al.*, 2000) with more inflated and more anteriorly located umbo and having more numerous teeth (11 anterior teeth and 18 posterior teeth in *T. kennerlyi*; Coan *et al.*, 2000) in which central teeth are large, thin and vertical to the hinge base. The present new species can be distinguished from the Recent cosmopolitan species, *Tindaria antarctica* Thiele, 1931 (in Thiele and Jaeckel, 1931) by having a more inflated umbo and coarser commarginal ribs.

Type Locality: Shimosasahara in Toyama City, central Honshu, Japan (36.569722N, 137.141389E); Higashi-bessho Formation; upper lower Miocene.

Distribution: Only from the type locality.

Etymology: Named for Mr. Toshikazu Hamuro in Imizu City, who collected the specimens of this species and made them available for this study.

DISCUSSION

Some molecular studies suggested that the common ancestor of the Tindariidae and Neilonellidae appeared in the Cretaceous (Sharma *et al.*, 2013; Sato *et al.*, 2020). However, the oldest fossil record of the the certain *Tindaria* so far dates to the Paleocene in the northwestern Pacific (Amano and Jenkins, 2017). The genus probably migrated to the northeastern part of the Pacific by the Oligocene (Kiel, 2006). During the Neogene, it spread to Europe and the Caribbean Region (Cossman and Peyrot, 1912; Woodring, 1925; Koskeridou *et al.*, 2019).

Most fossil species of *Tindaria*, including the oldest species and the type species, have a triangular or circular shell. Elongate ovate shells have not been found in the fossil record. For example, the extant *Tindaria compressa* Dall, 1908, *T. kennerlyi*, and *T. antarctica*, all have an elongate shell, but their fossils are not known. Thus the present ***Tindaria hamuroi* new species** represents the oldest

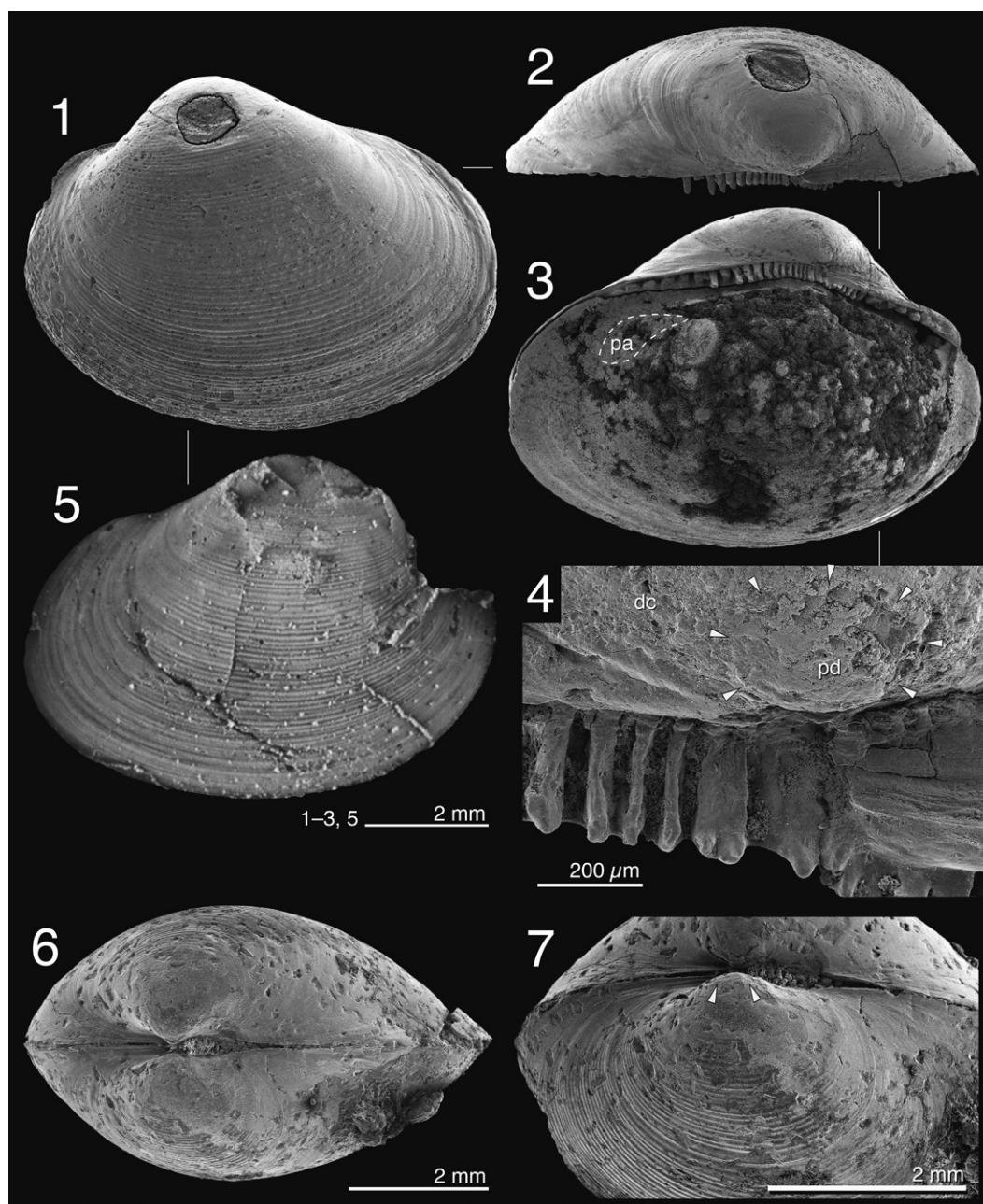


Figure 1–7. *Tindaria hamuroi* new species. 1–4. SEM micrographs. Left valve of **Holotype**, NMNS PM 65153a. 1. Lateral view. 2. Dorsal view. 3. Ventrally tilted inner view showing posterior adductor muscle scar (pa). 4. dorsal view of umbonal region, magnified from 2. 5. Silicone rubber mold of right valve of holotype, coated with ammonium chloride under normal right. NMNS PM 65153b. 6, 7. SEM micrographs. Paratype. NMNS PM 65154. Dorsal view and left umbonal region, respectively. 6 was taken tilted to right. Arrowheads denote boundary between dissoconch (dc) and prodissoconch (pd).

Tindaria having an elongate ovate shell. From these, *Tindaria* having an elongate shell appeared since the late early Miocene although the exact reason is unknown.

Based on other molluscan fossils from the Higashibessho Formation at Shimosahara, paleobathymetry can be inferred as lower sublittoral to upper bathyal (Amano *et al.*, 2004). In the living fauna, most species of this genus around Japan live at middle bathyal to abyssal depths

except for *Tindaria soyoae* Habe, 1953 and *T. jinxiingae* Xu, 1990 from upper bathyal depths (e.g., Xu, 1990; Xu, 1999; Kurozumi *et al.*, 2017). The relatively shallow depths of fossil *Tindaria* were also noted by Koskeridou *et al.* (2019), based on the estimated depth for their Pliocene species in the Mediterranean. In conclusion, a tendency to radiate into deeper waters has been recognized in *Tindaria*. Similar changes in their bathymetric distribution

have been recognized in the deep-sea bivalves having different feeding mode like as some chemosymbiotic species, such as vesicomyids and bathymodiolins. They now live mainly in waters deeper than the upper bathyal zone (Thubaut *et al.*, 2013; Lorion *et al.*, 2013; Okutani, 2017; Johnson *et al.*, 2017) whereas their fossils were recovered mainly from middle to upper bathyal deposits (e.g., Amano and Jenkins, 2007, Amano *et al.*, 2010). Although there is some criticism by Little *et al.* (2002), Callender and Powell (1999) stressed that the ancient chemosynthetic communities lived in shallower water than today partly because the predation pressure in the past was less in the shallow water than today.

Some deep-sea bivalves including *Tindaria* herein studied have been recorded from the lower to middle Miocene in the Japan Sea side of Japan. Other than *Tindaria*, these include the nucinellid *Nucinella*, the malletiid *Malletia*, the mytilid *Bathymodiolus* (s. l.), the cuspidariid *Myonera*, and the vesicomyids *Pliocardia* and *Calyptogena* (Tsuda, 1959; Amano *et al.*, 2001, 2010, 2019; Amano, 2007). “Ancistrolepidinae” [= Parancistrolepidinae; Kantor *et al.*, 2021] gastropods flourished in the Pliocene to early Pleistocene on the Japan Sea side but do not survive in the Japan Sea today (Amano *et al.*, 1996). All of them are deep-water taxa and became extinct in the Japan Sea as a result of the environmental change of semi-enclosed Japan Sea after the middle Miocene (*Nucinella*, *Tindaria*, *Bathymodiolus*, *Myonera*, *Pliocardia*), Pliocene (*Malletia*), early Pleistocene (Parancistrolepidinae) and middle Pleistocene (*Calyptogena*) (see also Amano, 2004).

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