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A new cardiid genus for *Cardium shiobarense* Yokoyama, 1926 and *Cardium angustum* Yokoyama, 1925 (Mollusca: Bivalvia)

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Abstract

A new bivalve genus, *Nipponocardium* is proposed for *Cardium shiobarense* (Yokoyama, 1926) (type species) and *C. angustum* (Yokoyama, 1925), an exceptional genus of Laevicardiinae in the northwestern Pacific Ocean. Among them, *Nipponocardium shiobarense* flourished in Honshu during the Late Miocene while *N. angustum* has been mainly recorded from the Pliocene and Lower Pleistocene deposits in the Japan Sea borderland. This genus became extinct by the end of the Early Pleistocene in Japan.

Key words: Bivalvia, Laevicardiinae, *Nipponocardium*, Omma-Mangani fauna, Shiobara-type fauna

1. Introduction

Cardium shiobarense Yokoyama, 1926 was proposed from the Upper Miocene Kanomatazawa Formation in Tochigi Prefecture, central Japan, based on poorly-preserved specimens (Pl. 1, Fig. E). Afterwards, Yokoyama (1931) illustrated a specimen from the Upper Miocene Kubota Formation in Fukushima Prefecture where preservation is better. Based on the characters of this specimen, *Cardium shiobarense* was identified from various localities mainly in northeastern Honshu. This species is a characteristic species of the Middle Miocene to Late Miocene Shiobara-type fauna (Chinzei and Iwasaki, 1967; Iwasaki, 1970) in northeastern Honshu corresponding to the Yama-Shiobara fauna of Chinzei (1963).

Because of poor preservation, the generic status of this species remained uncertain. Most paleontologists considered this species as *Laevicardium* Swainson, 1840, type genus of the subfamily Laevicardiinae (Kanno, 1960). When Amano (1983) focused on the presence of rather strong radial ribs as in the American genus *Dinocardium* Dall, 1900 of the Laevicardiinae, he treated it as "*Dinocardium*" *shiobarense*. Some paleontologists treated it under the American genus or subgenus *Trachycardium* Mörch, 1853, type genus of the subfamily Trachycardiinae since Nomura (1935), probably because this species has a high-oval shell with rather strong radial ribs. Recently, Kurihara (2010) illustrated rather small specimens having subcircular form and tentatively placed this species under the genus *Clinocardium* Keen, 1936 because he thought the similar radial ribs of this species to that of *Clinocardium.*

A smaller species, *Cardium angustum* Yokoyama, 1925 was proposed from the Pliocene Ogikubo

Formation in Nagano Prefecture (Pl. 1, Fig. G). This species is similar to *C. shiobarense* in having a high-oval shell and about 30 strong radial ribs. Amano and Koike (1983) illustrated it as "*Dinocardium*" *angustum* (Yokoyama).

Unfortunately, no one described and illustrated the hinge of *Cardium shiobarense* except for Noda et al. (1993) who illustrated the hinge of a right valve as *Vasticardium* cf. *angustum* (Yokoyama, 1925) [= *Cardium shiobarense* as described below]. However, the hinge of the left valve is not known. Usually, the radial ribs of fossil cardiids are not well preserved. This accounts for confusion concerning the generic placement of this species.

We examine the hinge and condition of radial ribs of *Cardium shiobarense* in detail on rather well-preserved specimens and also check the proportion of the specimens identified with *Cardium angustum*.

Institutional abbreviations: IGPS, Tohoku University Museum, Sendai, Japan; NMNS, Department of Paleontology and Anthropology, National Museum of Nature and Science, Tokyo, Tsukuba, Japan; UMUT, The University Museum, The University of Tokyo, Tokyo, Japan.

2. Materials

We have examined the type specimens stored at UMUT, six specimens in IGPS and seven specimens in NMNS of *Cardium shiobarense* were examined. Only one type specimen of *C. angustum* was also examined. The hinge morphology has hitherto remained unclear; however, sandblasting cleaning of specimens NMNS PM 21518 allows recognition of detailed features of both the right and left valves of *C. shiobarense*.

3. Systematic Paleontology

Class Bivalvia Linnaeus, 1758
Family Cardiidae Lamarck, 1809
Subfamily Laevicardiinae Keen, 1951

Genus ***Nipponocardium*** **new genus**

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Type species: *Cardium shiobarense* Yokoyama, 1926. Upper Miocene Kanomatazawa Formation in Tochigi Prefecture.

Etymology: This new genus is named after Japan (Nippon in Japanese). Neutral noun.

Diagnosis: Shell medium to large, rather thick, high-oval shape and well inflated. Surface sculptured by 30 to 42 strong and unsculptured radial ribs with narrow interspaces over whole surface (Pl. 1, Fig. F). Posterior margin not serrated. Umbo well produced above hinge margin with strongly prosogyrate beak. In right valve, anterior cardinal tooth (3a) small, just below antero-dorsal margin; posterior cardinal tooth (3b) large, slightly inclined posteriorly; anterior lateral tooth (AI) short; posterior lateral tooth (PI) short, behind rather long nymphal ridge (Pl 1, Fig. B). In left valve, anterior cardinal tooth (2) thin and vertical; posterior cardinal tooth (4b) thick and inclined posteriorly; anterior lateral tooth (AII) short, but distinct; posterior lateral tooth (PII) very short and weak; nymphal plate rather long and curved (Pl. 1, Fig. A). Lunule of both valves flat, wide and smooth not demarcated by incision (Pl. 1, Figs. C, D).

Remarks: Kurihara (2010) tentatively put the type species of *Nipponocardium* new genus into *Clinocardium* Keen, 1936 (Clinocardiinae Kafanov, 1975). However, Clinocardiinae is characterized by solid, rounded to ovate shells with strongly prosogyrate umbo and rather narrow hinge plate which are not observed in *Nipponocardium* new genus.

Judging from the high-oval shell, the unsculptured radial ribs, rather long nymphal ridge, and strong anterior lateral tooth, *Nipponocardium* new genus belongs to Laevicardiinae Keen, 1951, not to Trachycardiinae Stewart, 1930. The Recent Laevicardiinae consists of *Laevicardium* Swainson, 1840 and *Dinocardium* Dall, 1900. *Laevicardium* differs from *Nipponocardium* new genus by having weak radial ribs which are obsolete in the anterior and posterior parts and a smaller horizontal anterior cardinal tooth (3a) in the right valve.

Dinocardium shares a high-oval shell and many strong ribs with *Nipponocardium* new genus. However, *Dinocardium* can be easily distinguished from the new genus by having a lunule raised anterior to the umbo.

Included species: *Nipponocardium shiobarense* (Yokoyama, 1926) and *N. angustum* (Yokoyama, 1925).

***Nipponocardium shiobarense* (Yokoyama, 1926)**

[Japanese Name: Shiobara-zaru-gai]

(Pl. 1, Figs. A–F, H–J)

Cardium shiobarense Yokoyama, 1926, p. 134, pl. 20, figs. 2–5; Yokoyama, 1931, p. 202, pl. 12, fig. 1; Nomura and Onisi, 1940, p. 183, pl. 17, fig. 13.

? *Cardium* (*Cerastoderma*) *shiobarense* Yokoyama. Kuroda, 1931, p. 53.

Cardium (*Trachycardium*) *shiobarense* Yokoyama. Nomura, 1935, p. 80–81, pl. 4, figs. 1–3; Nomura and Hatai, 1936, p.125, pl. 15, fig. 4.

Laevicardium (*Trachycardium*) *angustum* (Yokoyama). Nomura and Hatai, 1937, p. 133, pl. 20, fig. 9. [*non Cardium angustum* Yokoyama]

Cardium (*Trachycardium*?) *shiobarense* Yokoyama. Nomura, 1940, p. 25, pl. 1, fig. 19.

Laevicardium shiobarense (Yokoyama). Kanno, 1960, p. 260–261, pl. 39, fig. 7; Iwasaki, 1970, p. 402–404, pl. 1, figs. 1, 2; Omori et al., 1976, fig. 4-3; Fujii and Shimizu, 1990a, pl. 1, fig. 7; Masuda et al., 1992, p. 33, pl. 3, fig. 4; Okumura and Ueda, 1998, p. 77, pl.12, figs. 4, 5; Yamauchi et al., 2000, fig. 9; Sakanoue, 2000, fig. 6-4; Nemoto and O'Hara, 2003, pl. 3, fig. 4.

Trachycardium shiobarense (Yokoyama). Makiyama, 1958, pl. 38, figs. 2–5; Makiyama, 1959, pl. 81, fig. 1; Mizuno, 1965, p. 33, pl. 1, fig. 9; Shikama, 1964, pl. 46, fig. 7.

"*Dinocardium*" *shiobarense* (Yokoyama). Amano, 1983, p. 45–46, pl. 3, fig. 15.

Laevicardium? *shiobarense* (Yokoyama). Takayasu, 1983, text-fig. 3.

Laevicardium cf. *shiobarense* (Yokoyama). Fujii and Shimizu, 1990b, pl. 1, fig. 9.

Vasticardium cf. *angustum* (Yokoyama). Noda et al., 1993, p. 154, figs. 18-5–9; Yamada and Koizumi, 1994, p. 84, figs. 2–10. [*non Cardium angustum* Yokoyama]

Vasticardium angustum (Yokoyama). Noda et al., 2004, p. 80, fig. 12-14. [*non Cardium angustum* Yokoyama]

Clinocardium shiobarense (Yokoyama). Kurihara, 2010, p. 57, figs. 24G, H.

Non Laevicardium shiobarense (Yokoyama). Ogasawara et al., 1989, pl. 11, fig. 10. [= *Clinocardium*? sp.]

Non Clinocardium ex gr. *shiobarense* (Yokoyama). Barinov et al., 1992, pl. 1, fig. 14. [= *Clinocardium*? sp.]

Type specimens: Lectotype, UMUT CM 22806; Paralectotypes, UMUT CM 22807, 22808, 22809; designated by Hatai and Nisiyama (1952) as the "holotype" and "paratypes", respectively.

Type Locality: Kanomatazawa, Nasu-Shiobara City, Tochigi Prefecture; Kanomatazawa Formation.

Material: Six specimens deposited in IGPS (IGPS 28420, 28417, 55367, 55368) and seven specimens deposited in NMNS (NMNS PM 11089, 21422, 21512, 21518, 58408) were also examined and measured. All of them were collected from the Upper Miocene Kubota Formation in Fukushima Prefecture.

Dimensions: *see* Table 1.

Remarks: According to Iwasaki (1970), the maximum size of this species attains 100 mm in height. The proportion of this species is usually higher than long (H/L = 0.98–1.25; average, 1.10). The number of ribs examined herein ranges from 30 to 38 (average, 33.6). According to Iwasaki (1970), this species has 33 to 42 radial ribs, based on 28 specimens.

Nipponocardium angustum (Yokoyama, 1925) (see below) was originally described from the Pliocene Ogikubo Formation at Shigarami in Nagano Prefecture. This species shares a high-ovate shell and a similar number of radial ribs (about 32 in the holotype). From the Ogikubo Formation, Nagamori (2014) illustrated the largest specimen of this species which is about 50 mm long (H/L = 1.50) and has 30 radial ribs. *Nipponocardium angustum* has a smaller (up to 50 mm in length) and more slender shell (H/L = 1.32–1.50) than *N. shiobarense* (up to 100 mm in length; H/L= 0.98–1.25).

Vasticardium cf. *angustum* (Yokoyama) and *V. angustum* (Yokoyama) were described from the Pliocene Kume Formation in Ibaraki Prefecture by Noda et al. (1993) and Noda et al. (2004), respectively. However, their specimens have a large high-ovate shell, attaining about 65 mm in length and 72 mm in height (H/L = 1.11) in fig. 18-9 by Noda et al. (1993). This proportion is within the range of

Nipponocardium shiobarense (Yokoyama) (see Table 1). Yamada and Koizumi (1994) described *Vasticardium* cf. *angustum* (Yokoyama) from the Pliocene Kanzawa Formation of the Nakatsu Group in Kanagawa Prefecture. According to them, the specimens attain 100 mm in height and have about 30 radial ribs. Moreover, Okumura and Ueda (1998) described *Laevicardium shiobarense* (Yokoyama) from the Kanzawa "Member" of the Nakatasu "Formation" in Kanagawa Prefecture. Thus, the specimens from the Nakatsu Group can be identified as *Nipponocardium shiobarense*.

Barinov et al. (1992) only illustrated *Clinocardium* ex gr. *shiobarense* (Yokoyama) from the Lower Miocene Pestrotsvetnaya Suite in Karaginsky Island. However, it is very difficult to understand why this specimen was compared with *Nipponocardium shiobarense* (Yokoyama) because of no similarity, no description and ill-preservation.

Stratigraphic distribution: Middle Miocene: Togeshita Formation in Hokkaido (Amano, 1983), Moniwa Formation in Miyagi Prefecture (Nomura, 1940), Saginosu Formation in Saitama Prefecture (Kanno, 1960), Ichibu, Omori and Fujina formations in Shimane Prefecture (Takayasu, 1986; Yamauchi et al., 2000; Sakanoue, 2000); Late Miocene: Narusawa Formation in Iwate Prefecture (Nomura, 1935), Yamatsuda Formation in Akita Prefecture (Masuda et al., 1992), Nanakita and Murata formations in Miyagi Prefecture (Nomura and Hatai, 1937; Nomura and Onisi, 1940), Kubota Formation in Fukushima Prefecture (Yokoyama, 1931; Nomura and Hatai, 1936; Iwasaki, 1970), Kanomatazawa Formation in Tochigi Prefecture (Yokoyama, 1926), Itahana Formation in Gunma Prefecture (Iwasaki, 1970; Kurihara, 2010), Mamioka Tuff in Gunma Prefecture (Omori et al., 1976), Otogawa Formation in Toyama Prefecture (Fujii and Shimizu, 1990a, b), Jinzai Formation in Shimane Prefecture (Takayasu, 1986); Pliocene: Kume Formation in Ibaraki Prefecture (Noda et al., 1993, 2004), Kanzawa Formation of Nakatsu Group in Kanagawa Prefecture (Yamada and Koizumi, 1994; Okumura and Ueda, 1998).

Table 1. Measurements of *Nipponocardium shiobarense* (Yokoyama, 1926). H = shell height, L = shell length, NR = Number of radial ribs. Valve: R, rignt; L. left.

Specimens	Type status	L (mm)	H (mm)	H/L	NR	Valve	Formation
UMUT CM 22806	Lectotype	58.3	64.7	1.11	31+	R	Kanomatazawa F.
UMUT CM 22807	Paralectotype	42.0	41.2	0.98	-	R	Kanomatazawa F.
UMUT CM 22808	Paralectotype	41.0	40.3	0.98	-	L	Kanomatazawa F.
UMUT CM 22809	Paralectotype	47.0	45.6+	-	-	L	Kanomatazawa F.
IGPS 28417		69.1	76.1	1.10	30	R	Kubota F.
IGPS 28417		74.4	83.7	1.13	35+	L	Kubota F.
IGPS 28420		68.7	70.0	1.02	38	R	Kubota F.
IGPS 28420		68.3	74.2	1.09	31	L	Kubota F.
IGPS 55367		64.5	63.3	0.98	32	L	Kubota F.
IGPS 55368		61.0	67.8	1.11	36	L	Kubota F.
NMNS PM 11089		62.4	63.9	1.02	31+	R	Kubota F.
NMNS PM 21422		72.8	81.7	1.12	30	R	Kubota F.
NMNS PM 21512-1		68.5	78.2	1.14	34	R	Kubota F.
NMNS PM 21512-2		63.9	74.2	1.16	34	R	Kubota F.
NMNS PM 21518-1		71.0	82.6	1.16	34	L	Kubota F.
NMNS PM 21518-2		67.5	78.6	1.16	34	R	Kubota F.
NMNS PM 58408		59.6	74.4	1.25	32	L	Kubota F.

***Nipponocardium angustum* (Yokoyama, 1925)**

[Japanese name: Togari-zaru-gai]

(Pl. 1, Fig. G)

Cardium angustum Yokoyama, 1925, p. 13, pl. 4, fig. 2.

Cardium (*Laevicardium*) *angustum* Yokoyama. Kuroda, 1931, p. 53–54, pl. 5, fig. 30.

Laevicardium angustum (Yokoyama). Kanno and Tomizawa, 1959, pl. 2, fig. 4; Kanno, 1960, p. 259–260, pl. 39, figs. 14a, b; Okumura and Yamagishi, 1992, figs. 3.3a–b.

Trachycardium angustum (Yokoyama). Itoigawa and Shibata, 1977, pl. 26, fig. 4; Ogasawara et al. 1983, pl. 1, figs. 17A, B.

"*Dinocardium*" *angustum* (Yokoyama). Amano and Koike, 1993, pl. 2, fig. 7; Amano and Sato, 1994, fig. 3-6; Amano et al., 2000, pl. 1, figs. 7, 13, 14; Amano et al., 2008, fig. 4-5; Amano et al., 2009, fig. 6-3; Amano, 2024, pl. 1, fig. 7.

Dinocardium angustum (Yokoyama). Nagamori, 2000, pl. 9, figs. 1a, b; Nagamori, 2014, p. 24, pl. 9, figs. 1a, b.

Type specimens: Lectotype (herein designated), UMUT CM 22599. Although Hatai and Nisiyama (1952) assigned this specimen to the holotype, it is obvious that the description by Yokoyama (1925) was made based on two specimens. Ichikawa (1983) treated UMUT CM 22599 and 22600 as the syntype. However, unfortunately, one specimen UMUT CM 22599 is now only stored at the University Museum of University of Tokyo. Based on this, we designate UMUT CM 22599 illustrated by Yokoyama (1925, pl. 4, Fig. 2) to the lectotype.

Type Locality: Shigarami, Nagano City, Nagano Prefecture; Ogikubo Formation.

Dimensions: Length = 31.5 mm; Height = 41.7 mm; H/L = 1.32; Number of radial ribs = 32.

Remarks: *Cardium angustum* Yokoyama, 1925 is medium-sized, about 50 mm long (Nagamori, 2014, pl. 9, fig. 1a; Ogasawara et al., 1983, pl. 1, figs. 17A, B), with a high-oval and well inflated shell. The surface is sculptured by 30 to 32 strong and unsculptured radial ribs with narrow interspaces. The posterior margin is not serrated. The umbo is well produced above the hinge margin. In the left valve, the anterior cardinal tooth is vertical to the hinge base and the posterior cardinal is thick and inclined posteriorly (see Amano et al., 2000, pl. 1, fig. 7). All these features are characteristics of *Nipponocardium* new genus.

Stratigraphic distribution: Middle Miocene: Saginosu Formation in Saitama Prefecture (Kanno, 1960); Late Miocene: Shiotsubo Formation in Fukushima Prefecture (Ogasawara et al., 1983), Ogawa Formation in Nagano Prefecture (Kanno and Tomizawa, 1959; Amano and Koike, 1993); Pliocene: Hatsuse Formation in Kanagawa Prefecture (Okumura and Yamagishi, 1992), Tentokuji Formation in Akita Prefecture (Amano et al., 2000), Joshita and Ogikubo formations in Nagano Prefecture (Yokoyama, 1925; Amano and Sato, 1994; Nagamori, 2000, 2014) and Mita Formation in Toyama Prefecture (Amano et al., 2008); Early Pleistocene: Lowest part of Uonuma Group in Niigata Prefecture (Amano et al., 2009).

4. Discussion

Most species of Laevicardiinae live in the Atlantic Ocean, and a few species live in the tropical eastern Pacific while Trachycardiinae species are found in warm-waters throughout the tropics (ter Poorten, 2024). According to Keen (1973), one Recent and five fossil species of *Laevicardium* are recognized in Japan: *L. pulcherrimum* Sakurai and Habe, 1966; *L. angustum* (Yokoyama, 1925); *L. pigmae* Shuto, 1960; *L. shiobarense* (Yokoyama, 1926); *L. taracaicum* (Yokoyama, 1930) and *L. yoshidense* Kanno, 1958. Of these, the Recent species *L. pulcherrimum* is considered a junior synonym of the trachycardiine *Acrosterigma transcendens* (Melvill and Standen, 1899) by ter Poorten (2024). As described above, *L. shiobarense* and *L. angustum* are now allocated to the new genus *Nipponocardium*. *Nipponocardium* species are exceptional cases of Laevicardiinae in the Northwestern Pacific Ocean.

Both *Nipponocardium shiobarense* and *N. angustum* first appeared in the Middle Miocene. *Nipponocardium shiobarense* flourished in the Late Miocene and was distributed from northeast Honshu to southwestern Honshu. Thus, this species is a representative member of the Shiobara-type fauna (Chinzei and Iwasaki, 1967; Iwasaki, 1970). Shuto (1961) only listed this species from the Upper Miocene Boroishi Member of the Miyazaki Group in Miyazaki Prefecture,

southeastern Kyushu. However, as he did not illustrate the specimen, and it is uncertain whether this species lived in the warm-water area of Kyushu or not. This species survived until the Pliocene in the Kanto area, Pacific side of central Honshu. In the Pliocene, this area corresponded to the "Transitional Zone" (Noda and Amano, 1977) where some representative species of the warm-water Kakegawa fauna (Otuka, 1939b) and the cold-water Tatsunokuchi (Nomura, 1938) and Omma-Manganji fauna (Otuka, 1939a) were recorded. In contrast, *Nipponocardium angustum* flourished in the Japan Sea borderland during the Pliocene. In other words, it is one of the representative species of the Omma-Manganji fauna. However, as no fossil of either species has been recorded from Middle Pleistocene deposits, the genus *Nipponocardium* became extinct by the end of the Early Pleistocene.

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Plate 1

Figs. A–F, H–J. *Nipponocardium shiobarense* (Yokoyama, 1926).

Figs. A, C, I. NMNS PM 21518-1, left valve. A, hinge. C, dorsal view. I. outer surface. Loc. Hanawa Town, Higashishirakawa-gun, Fukushima Prefecture. Kubota Formation.

Figs. B, D, H. NMNS PM 21518-2, right valve. B, hinge. D, dorsal view. H, outer surface. Loc. Hanawa Town, Higashishirakawa-gun, Fukushima Prefecture. Kubota Formation. This specimen was illustrated in Nomura and Hatai (1936, pl. 15, fig. 4).

Fig. E. UMUT CM 22806, lectotype, right valve. Loc. Shiobara, Nasu-Shiobara City, Tochigi Prefecture. Kanomatazawa Formation.

Fig. F. IGPS 28420, right valve. Loc. Nishigochi-Kotaki, Hanawa Town, Fukushima Prefecture. Kubota Formation.

Fig. J. IGPS 55368, left valve. Loc. Kamitoyo, Hanawa Town, Higashi-ishirakawa-gun, Fukushima Prefecture. Kubota Formation.

Fig. G. *Nipponocardium angustum* (Yokoyama, 1925). UMUT CM 22599, lectotype, left valve. Loc. Shigarami, Nagano City, Nagano Prefecture.

Abbreviations: AI = anterior lateral tooth of the right valve, AII= anterior lateral tooth of the left valve, lu = lunule, PI= posterior lateral tooth of the right valve, PII= posterior lateral tooth of the left valve.

All scale bars show 10 mm.

Plate 1