

A Paleocene species of *Procardia* (Bivalvia: Anomalodesmata: Parilimyidae) from the Katsuhira Formation in Urahoro Town, eastern Hokkaido, Japan

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ABSTRACT

A new species of anomalodesmatan bivalve, *Procardia inouei*, is described from the Paleocene (upper Selandian to lowest Thanetian) Katsuhira Formation in eastern Hokkaido, Japan. The genus *Procardia* flourished during the late Jurassic to Cretaceous, and this new species is the first Paleocene record of *Procardia*. *Procardia* clearly survived the end-Cretaceous mass extinction, and includes the late Eocene to early Miocene species *P. dolicha* (Suter, 1917) from New Zealand. The Recent species of *Panacca* Dall, 1905 can be distinguished from *Procardia* easily, but possibly were evolutionally derived from *Procardia*.

Additional Keywords: Paleocene, bivalve, *Procardia*, new species, *Panacca*

INTRODUCTION

The parilimyid genus *Procardia* Meek, 1871 is one of the characteristic Mesozoic anomalodesmatan bivalves. Fossils of this genus have been found from the Upper Jurassic in Spain, the Lower Cretaceous in England, the Cenomanian in the United States Western Interior Sea and the Maastrichtian in Germany, Poland, Ukraine and Russia (Woods, 1909; Cox and Newell in Cox et al., 1969; Runnegar, 1974; Jablonski and Raup, 1999; Olóriz et al., 2003). Only one younger species has been recorded, the early Eocene to early Miocene species *Procardia dolicha* (Suter, 1917), from the South Island of New Zealand (Beu and Maxwell, 1990, p. 132, pl. 9h, i). Beu and Maxwell (1990) considered this species to be a relict from the Mesozoic Era in New Zealand.

On the other hand, *Procardia* is very similar to *Panacca* Dall, 1905, which now lives in lower sublittoral to abyssal depths. Eight species of *Panacca* are known, from off West Africa, Meteor Seamounts, Massachusetts, Chile, Indonesia, southwestern Japan and Tasmania (Coan, 2000; Krylova, 2006; Sasaki and Okutani, 2007). They are

carnivores or scavengers, burrowing in soft mud, and do not prefer cold waters (Morton, 1981, 1982; Huber, 2010). Probably because of their ecology and their fragile shell, their occurrence is so scarce that *Panacca africana* (Locard, 1898), *P. chilensis* Coan, 2000, *P. montana* Krylova, 2006, and *P. trigona* Sasaki and Okutani, 2007 were each based on a single specimen. However, there is no fossil record of this genus. *Panacca* differs from *Procardia* mainly by lacking a lunule.

One articulated bivalve specimen of *Procardia* has been collected from the Paleocene Katsuhira Formation (late Selandian to earliest Thanetian; see Amano et al., 2018) in eastern Hokkaido by Mr. K. Inoue (Obihiro City). I describe this species as new and discuss the relationship between *Procardia* and *Panacca*.

MATERIALS AND METHODS

One articulated specimen of *Procardia inouei* new species was obtained from the dark gray mudstone of the Katsuhira Formation exposed along the Urahoro River, 30 m north of the mouth of the Kokatsuhirazawa River, Urahoro Town, eastern Hokkaido (Figure 1; 42°59'12" N, 143°37'35" E). The new species was associated with *Meganuculana alleni* Amano and Jenkins, 2017, *Thyasira?* sp., *Neverita majimai* Amano and Jenkins, 2018, *Kangilioptera inouei* Amano and Jenkins, 2014 and *Biplica paleocenica* Amano and Jenkins, 2018. As observed by Amano et al. (2018), it is estimated that the Katsuhira Formation was deposited at a depth of 200 to 500 m.

The holotype of the new species is catalogued in the University Museum of the University of Tokyo (UMUT). The associated fauna is stored at College of Science and Engineering, Kanazawa University.

SYSTEMATIC PALEONTOLOGY

Superfamily Pholadomyoidea King, 1844

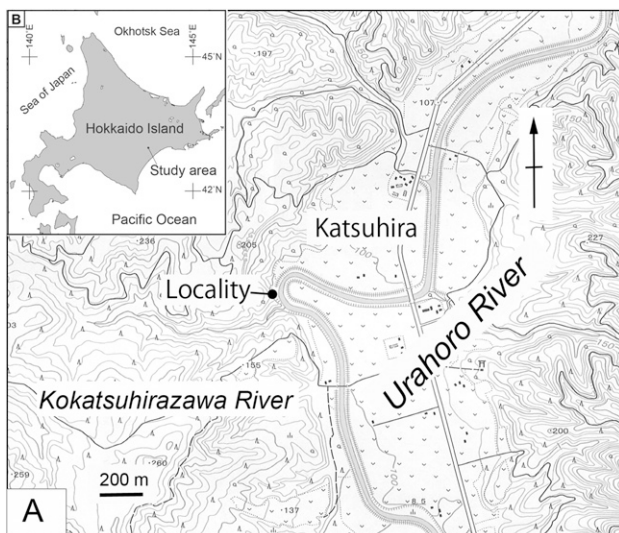


Figure 1. Map showing the type locality of *Procardia inouei* new species. Base map from “Katsuhira,” original scale 1:25,000; topographical map published by the Geospatial Information Authority of Japan.

Family Parilimyidae Morton, 1981

Remarks: This family was separated from Pholadomyidae King, 1844 based mainly on anatomical characters, by Morton (1981, 1982). Judging from the fossil record (Runnegar, 1974), Pholadomyoidea should be allocated on the basal part of the bivalve phylogenetic tree. Although the molecular sphylogeny of the Anomalodesmata has been examined by Dreyer et al. (2003) and Harper et al. (2006), Pholadomyoidea have not been included, probably because living specimens are difficult to obtain. Coan (2000), Krylova (2006), and Sasaki and Okutani (2007) mistakenly attributed the family Parilimyidae to Morton (1982). Morton (1981) had already proposed this family, as indicated by Huber (2010). When Coan (2000) included two genera, *Parilimyia* Melvill and Standen, 1899 and *Panacca* Dall, 1905, he considered *Nipponopanacca* Habe, 1977 to be a synonym of *Parilimyia*. However, as Matsukuma (1989) discussed, by comparing it with the type species of *Pholadomya*, *P. candida* G. B. Sowerby I, 1823, *Nipponopanacca* should be treated as a subgenus of *Pholadomya* G. B. Sowerby I, 1823 (see also Okutani, 2017). Runnegar (1974) suggested that *Panacca* is a junior synonym of the Mesozoic genus *Procardia* Meek, 1871. As discussed below, the genus *Panacca* is separated from *Procardia*, which is also included in Parilimyidae. Moreover, judging from its shape and shell sculpture, *Kanakimya* Campbell and Grant-Mackie, 1995, from Middle Jurassic rocks of New Caledonia, should be included in this family.

Genus *Procardia* Meek, 1871

Type Species: *Isocardia*[?] *hodgei* Meek, 1871 by original designation.

Remarks: *Procardia* is characterized by having an anteriorly truncated triangular shell, slightly higher than long or with height nearly equal to length, radial ribs present over the whole surface apart from the anterior flat area, some commarginal ribs or distinct growth lines, and a distinct lunule on the flat area. The Recent genus *Panacca* Dall, 1905 differs from *Procardia* by its longer shell and by having no radial ribs on the posterior end. Moreover, as pointed by Beu and Maxwell (1990), species of *Panacca* lack a lunule on the anterior flat area. *Kanakimya* was proposed by Campbell and Grant-Mackie (1995) as a subgenus of *Pholadomya* from Middle Jurassic rocks in New Caledonia, based on only one species, *Pholadomya* (*Kanakimya*) *uito*e Campbell and Grant-Mackie, 1995. *Kanakimya* differs from *Procardia* by having a sub-truncated posterior margin and no radial ribs on the posterior surface, although it is similar to *Procardia* in having a high shell with an anterior flat area and a lunule.

Procardia inouei new species

(Figures 2–5)

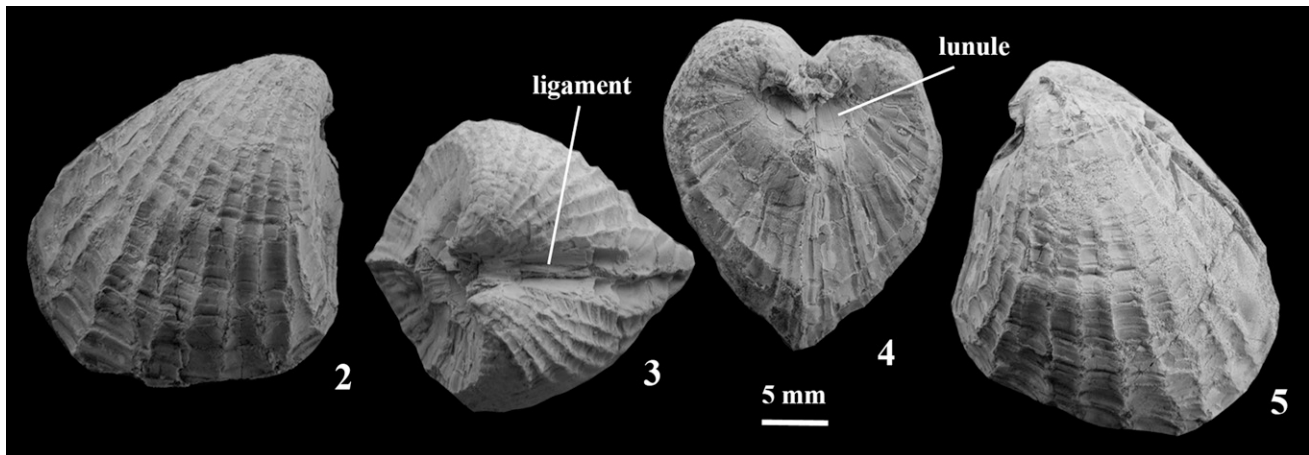
Diagnosis: Small, trigonal *Procardia* sculptured with 13 radial ribs. Radial ribs with central crest and gently sloping sides; interspaces each wider than one rib. Anterior flat area sculptured only with fine growth lines; with distinct lunule.

Description: Shell fragile, nacreous inside, small (24.9 mm in length), trigonal, slightly higher than long (height 25.2 mm), equivalve, extremely inequilateral. Posterior dorsal margin long, broadly arched, gradually merging into subcircular posterior margin; ventral margin nearly straight; anterior dorsal margin short; anterior margin slightly concave, truncated. Umbo well inflated, located at anterior one-eighth (12.4 %) of shell. Whole surface apart from anterior flat area sculptured with 13 radial ribs, each with central crest, gently sloping sides, and fine growth riblets; interspaces each wider than rib width. Anterior flat area sculptured with distinct fine growth lines. Lunule rather wide, moderately depressed, bounded by rough ridge. Escutcheon depressed, lanceolate, between strong radial ribs of both valves. Ligament external, occupying half of postero-dorsal margin. Interior characters unknown.

Type Material: Holotype: UMUT CM 33112 (length 24.9 mm; height, 25.2 mm; depth, 21.5 mm).

Type Locality: Cliff along Urahoro River, 30 m north of the mouth of Kokatsuhirazawa River, Urahoro Town, eastern Hokkaido, Japan.

Remarks: *Procardia inouei* new species is similar to *Procardia decussata* (Mantell, 1822) from the Cretaceous Chalk in southeastern England. Both have a triangular shell with radial ribs and growth riblets and a wide anterior flat area. However, the present new species is smaller (*P. decussata* attains 98mm in length; Woods, 1909) and has fewer radial ribs than *P. decussata* (*P. decussata* has 18 radial ribs, which are fine on the posterior area).



Figures 2–5. *Procardia inouei* new species (holotype, UMUT CM 33112) from the Katsuhira Formation. **2.** Lateral view of right valve. **3.** Dorsal view. **4.** Anterior view. **5.** Lateral view of left valve.

Procardia hodgei (Meek, 1871), the type species of *Procardia*, from the Campanian Pierre Shale in the Interior Sea Way area in the USA, differs from the present new species by having many rounded radial ribs and distinct commarginal growth ribs (see Meek, 1876; Runnegar, 1974).

Marwick (1944) described *Cardium (Fragum) dolichum* Suter, 1917 and *C. (F.) maorinum* Suter, 1917, both with type specimens from the lower to middle Oligocene in the South Island of New Zealand, and referred both to *Procardia dolicha*. Beu and Maxwell (1990, p. 132, pl. 9h, i) illustrated this species and recorded it from late Eocene to early Miocene rocks in New Zealand. *Procardia dolicha* differs from *P. inouei* new species by having a larger shell (55 mm in length), more numerous radial ribs (25 to 28) and a narrower flat area with a more distinctly demarcated lunule.

Etymology: The new species is named for Kiyokazu Inoue (Obihiro City), the collector of the holotype.

Distribution: Known only from the type locality, in the upper Selandian to lowest Thanetian Katsuhira Formation, Urahoro Town, eastern Hokkaido.

DISCUSSION

This is the first record of *Procardia* in the Paleocene and from the northern Pacific region. As already mentioned by Beu and Maxwell (1990), this genus survived the end-Cretaceous mass extinction in New Zealand. Nine species or genera from the Katsuhira Formation were able to survive this event, partly because they lived in deep water (Amano et al., 2018). *Procardia inouei* new species is added to the relict forms from the Mesozoic fauna.

The oldest *Procardia* sp. is recorded from an Upper Jurassic carbonate with siliceous sponges in southern

Spain (Olóriz et al., 2003). In the Cretaceous, species of *Procardia* are widespread in Europe and US Interior Sea Way (Woods, 1909; Jablonski and Raup, 1999). However, there is no record of this genus from the Cretaceous in Japan (Nagao, 1943; Hayami, 1975; Tanaka and Toshimitsu, 2003). The migration route of this genus to Japan during the Paleocene is uncertain.

On the other hand, the present-day genus *Panacca* has a world-wide distribution in warm and relatively deep waters, but has no fossil record (Coan, 2000; Krylova, 2006; Sasaki and Okutani, 2007). The New Zealand relict species *Procardia dolicha* (Suter, 1917) is unusual in having a rather elongate shell similar to *Panacca*. However, the presence of radial ribs on whole surface and a lunule, which are characters of *Procardia*, were described and illustrated in *P. dolicha* by Marwick (1944) and Beu and Maxwell (1990). It is uncertain, but the elongate shape of *P. dolicha* suggests the possibility that *Panacca* evolved from *Procardia*.

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