

A new Paleocene species of *Myonera* (Bivalvia: Cuspidariidae) from eastern Hokkaido, northern Japan

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ABSTRACT

The cuspidariid bivalve, *Myonera inouei* new species, is described from a Paleocene (upper Selandian) calcareous concretion probably derived from the Tomikawa Sandstone and Conglomerate Member in eastern Hokkaido, northern Japan. This is the oldest record of this genus. *Myonera inouei* possibly lived in upper bathyal depths. It provides another example of taxa of deep-sea origin in the Paleocene. **The senior author, Kazutaka Amano, is the single author of the new species.**

Additional Keywords: Marine, fossil, deep-sea origin

INTRODUCTION

Deep-sea predatory bivalves of the Cuspidariidae are the most diversified group among the septibranch bivalves, and include 19 genera and 254 species (Morton and Machado, 2019). According to the previous studies, the oldest unequivocal fossil record of Cuspidariidae was a Maastrichtian species of *Cuspidaria* Nardo, 1840 (Runnegar, 1974; Heinberg, 1979) although there are some doubtful records from Triassic and Jurassic brackish sediments (Harper et al., 2002). Recently, a probably cuspidariid new genus, *Neuquemya*, has been proposed from the lower Jurassic (Pliensbachian) shallow-sea deposits in Argentina (Damborenea, 2019). From the above, it is uncertain whether Cuspidariidae had a shallow water origin or not. In her description of two new species of *Cardiomya* Adams, 1864 from the upper Eocene to lower Oligocene Keasy Formation in Oregon, Hickman (2014) discussed the radiation that Cuspidariidae has undergone in the deep sea during the Cenozoic.

Other than *Cuspidaria* and *Cardiomya*, few fossils of other cuspidariids have been recorded from Cenozoic deposits. Within the family, only two fossil species of *Myonera* have been recorded: *Myonera* sp. from the lower Oligocene Makah Formation in Washington State, USA (Goedert, 1995) and *M. osawanoensis* (Tsuda, 1959)

from the lower Miocene Kurosedani Formation in Toyama Prefecture, central Honshu, Japan (Tsuda, 1959) and the middle Miocene Arakawa Formation in Saitama Prefecture, central Honshu, Japan (Kurihara, 1999).

We have found a new species of *Myonera* from the Paleocene Tomikawa Sandstone and Conglomerate Member of Tomikawa Formation (Nishijima, 1964) in eastern Hokkaido, northern Japan. We describe this new species and discuss its evolutionary significance.

MATERIALS AND METHODS

A floating calcareous concretion yielding a new species of *Myonera* was collected from a locality 550 m upstream in a small creek, a tributary of the Mokawaruppu River (43°3'36" N, 143°40'47" E; Figure 1). This concretion consists of calcareous sandy mudstone without any plant fragments. In outcrops around this locality, dark gray mudstone including calcareous concretions is intercalated with conglomerates. According to the geological map by Nishijima (1964), this locality corresponds to the Tomikawa Sandstone and Conglomerate Member of the Tomikawa Formation of the Nemuro Group.

Three specimens of an unknown *Myonera* species were extracted from the calcareous concretion in association with *Parathyasira* sp., *Procardia* sp., *Cochlodesma*? sp. and *Epilucina*? sp. Dinoflagellate cysts were picked from the same concretion for age determination. Taxonomic allocation of dinoflagellate cysts follows Fensome et al. (2008), where complete bibliographic references were provided. The sample was treated successively with HCl and HF to eliminate carbonate and silicate minerals. Then heavy liquid zinc bromide (specific gravity 2.0) was used to concentrate organic particles from the residues after the acid treatment.

We used digital calipers (Mitsutoyo Company, model CD-20) to measure specimens of *Myonera* species to the first decimal place. All specimens of *Myonera* species are deposited at the National Museum of Nature and Science, Tsukuba (NMNS).

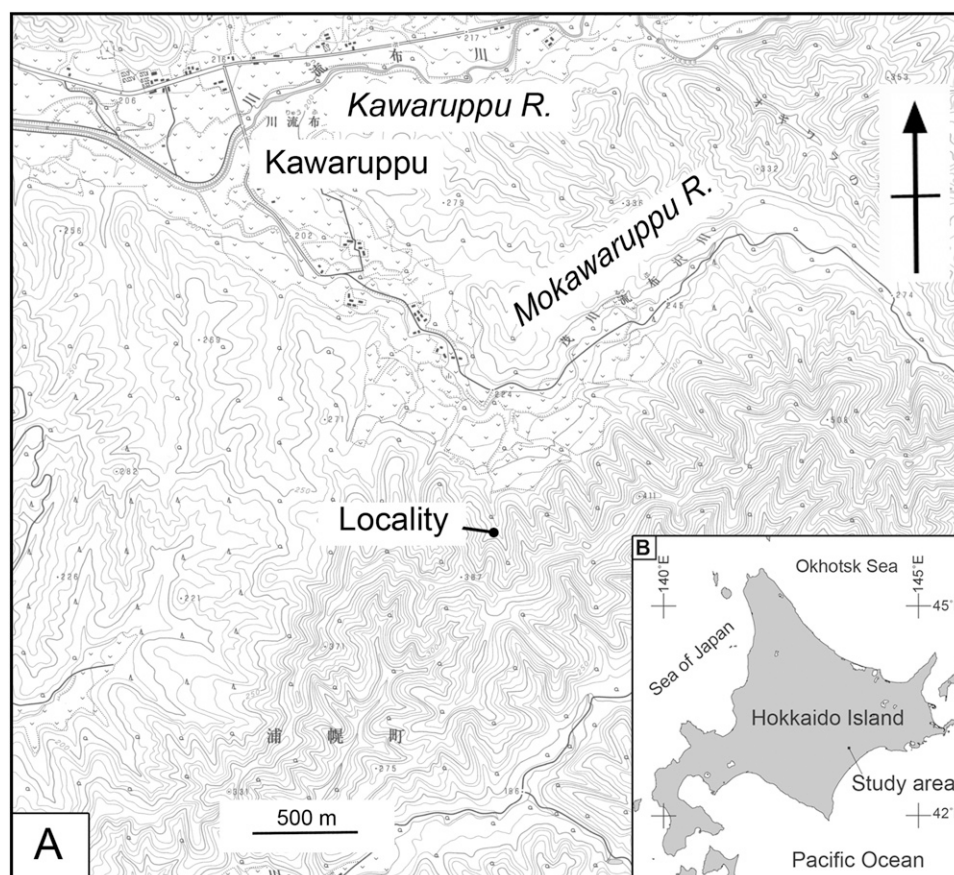


Figure 1. Locality of fossils. Base map from “Kawaruppu”, original scale 1:25,000; topographical map published by the Geospatial Information Authority of Japan.

DINOFLAGELLATE-CALIBRATED AGE OF THE CALCAREOUS CONCRETION

The concretion yielded a number of dinoflagellate cysts whose preservation was sufficiently good for identification. Based on sixty-seven counted specimens, the dinoflagellate cyst assemblage is characterized by abundant to common occurrences of *Areoligera volata*, *Operculodinium centrocarpum*, and *Senegalinium microspinosum*, with fewer specimens of *Areoligera coronata*, *Cannosphaeropsis utinensis*, *Hystriosphæridium tubiferum*, *Lejeunecysta granosa*, *Manumiella rotunda*, *Palaeocystodinium golzowense*, and *Trithyrodinium evittii* (Table 1). In addition, presence of an acritarch (general name for organic-walled microfossils of apparently unicellular organisms whose biological affinity are not clear) species *Paralecaniella indentata* was also recorded. The occurrences of *Hystriosphæridium tubiferum*, *Palaeocystodinium golzowense*, *Senegalinium microspinosum*, and *Trithyrodinium evittii*, as well as the acritarch species *Paralecaniella indentata*, confirm correlation with the *Palaeocystodinium golzowense* Biozone defined by Kurita (2004). This zone was established in the same area in Hokkaido. According to the original age calibration (Kurita, 2004), this biozone indicates a late Selandian age. Other recorded species,

including *Cannosphaeropsis utinensis*, *Lejeunecysta granosa* and *Manumiella rotunda*, are consistent with this age.

SYSTEMATICS

Family Cuspidariidae Dall, 1886

Genus *Myonera* Dall and Smith in Dall, 1886

Type Species: *Myonera paucistriata* Dall, 1886 by original designation.

Remarks: The genus *Myonera* closely resembles *Bathyneæra* Scarlato and Strabogotov, 1983 in having a rostrate shell outline and both commarginal and radial ribs. However, *Myonera* species usually has one or two strong radial ribs and a short rostrum (Krylova, 1993; Coan et al., 2000; Coan and Valentich-Scott, 2012). *Myonera* species are also similar to *Thermomya* Chen, Okutani, Watanabe, and Kojima, 2018 from a hydrothermal vent site in the southern Mariana Trough in having some commarginal ribs and a short rostrum without commarginal ribs. However, as Chen et al. (2018) pointed out, *Myonera* species have more rounded commarginal ribs and distinct radial ribs. Species in the

Table 1. List of dinoflagellate cysts and acritarchs associated with the molluscan fossils. Relative abundance of each dinoflagellate cyst taxon is expressed as VA (very abundant, 20 % and more of the total specimen count), A (abundant, 20-10 %), C (common, 10-8 %), R (rare, 8-5 %) and VR (very rare, less than 5 %).

Species	Abundance
DINOFLAGELLATA	
<i>Achomospaera ramulifera</i> (Deflandre, 1937) Evitt, 1963	VR
<i>Areoligera coronata</i> (Wetzel, 1933 ex Deflandre, 1937) Lejeune-Carpentier, 1938	R
<i>Areoligera volata</i> Drugg, 1967	VA
<i>Cannosphaeropsis utinensis</i> Wetzel, 1933	VR
<i>Hystichosphaeridium tubiferum</i> (Ehernberg, 1838) Deflandre, 1937, emend. Davey and Williams, 1966	VR
<i>Lejeunecysta granosa</i> Biffi and Grignani, 1983	VR
<i>Manumiella rotunda</i> Wilson, 1988	VR
<i>Operculodinium centrocarpum</i> (Deflandre and Cookson, 1955) Wall, 1967	A
<i>Palaeocystodinium golzowense</i> Alberti, 1961	R
<i>Phelodinium</i> sp. indet.	VR
<i>Senegalinium microspinosum</i> (Boltenhagen, 1977) Lentin and Williams, 1980	A
<i>Spiniferites</i> sp.	VR
<i>Trithyrodinium evitti</i> Drugg, 1967	VR
ACRITARCHA	
<i>Paralecaniella indentata</i> (Deflandre and Cookson, 1955) Cookson and Eisenack, 1970, emend. Elsik, 1977	VR

Jurassic genus *Neuquemya* Damborenea, 2019 have a small, inflated shell, a short, smooth rostrum, and some very flat radial ribs with narrow interspaces behind some commarginal ribs on the anterior half of disc. Flat radial ribs are not present in *Myonera*. *Neaeroporomya* Cossmann, 1886 of the family Poromyidae is similar to *Myonera* in having a short rostrum, two radial ribs and commarginal ribs on the anterior part of the disc. However, the type species of *Neaeroporomya* has an inner nacreous layer and one hinge tooth, whereas *Myonera* species lack a nacreous layer and have no hinge teeth.

***Myonera inouei* Amano new species**
(Figures 2–4)

Diagnosis: Small *Myonera* species with a rather short rostrum; main disc sculptured with 14 to 25 raised commarginal ribs with deep, narrow interspaces; rostrum smooth, separated from main disc by sharp radial ridge.

Description: Shell small (to 8.8 mm long), elongate ovate, longer than high ($H/L = 0.64$ to 0.80), thin, subequilateral ($AL/L = 0.44$ to 0.47), subdivided into anterior main disc and rather short rostrum by posteriorly oblique, sharp radial ridge extending from beak. Antero-dorsal margin broadly arcuate; antero-ventral margin well-rounded; postero-ventral margin of rostrum slightly concave before postero-ventral corner; postero-dorsal margin nearly straight, gently sloping; posterior margin narrowly subtruncated. Surface of main disc sculptured with 14 to 25 closely spaced, raised commarginal ribs. Rostrum smooth or sculptured with a few obsolete commarginal ribs, and one weak blunt radial ridge extending from beak to postero-ventral corner. Inner ventral margin smooth. As shell material of rostrum of holotype dissolved, inner part of shell observable. Posterior adductor muscle scar rather large and elongate along dorsal margin. Pallial sinus shallow and bluntly pointed.

Holotype: Right valve (NMNS PM no. 28357), length 8.4 mm, height 5.4 mm.

Paratypes: Left valve (NMNS PM nos. 28358), length 5.5 mm, height 4.4 mm; left valve (NMNS PM nos. 28359), length 8.8 mm+, height, 6.4 mm.

Type Locality: 550m upstream of small creek of Mokawaruppu River, Urahoro Town; Tomikawa Sandstone and Conglomerate Member of Tomikawa Formation; late Selandian.

Material Examined: Three specimens from the type locality.

Remarks: The senior author, Kazutaka Amano, is the single author of the new species. Occurrences of fossil *Myonera* species are very rare. Goedert (1995) described *Myonera* sp. from the lower Oligocene Makah Formation in Washington State as the first fossil record. As he noted, this specimen looks like the Recent species *Myonera tillamookensis* Dall, 1916 (= *Bathyneaea tillamookensis*) in having at least four radial ribs on the rostrum and rough, prominent commarginal ribs on the anterior main disc. Another fossil species, *Myonera osawanoensis* (Tsuda, 1959) had been recorded from the lower Miocene Kurosedani Formation and middle Miocene Arakawa Formation, both in central Honshu, Japan (Kurihara, 1999). *Myonera osawanoensis* is characterized by a very short rostrum and a main disc ornamented with weak commarginal ribs; it resembles the Recent species *Myonera dautzenbergi* Prasad, 1932. ***Myonera inouei* new species** is the oldest record of this genus.

***Myonera inouei* new species** surprisingly resembles the Recent *Myonera angularis* (Jeffreys, 1876), which lives in deep water (530–4715m) in the North Atlantic and the Mediterranean Sea (Salas, 1996; Janssen and Krylova, 2014). The two species share a rather short as well as

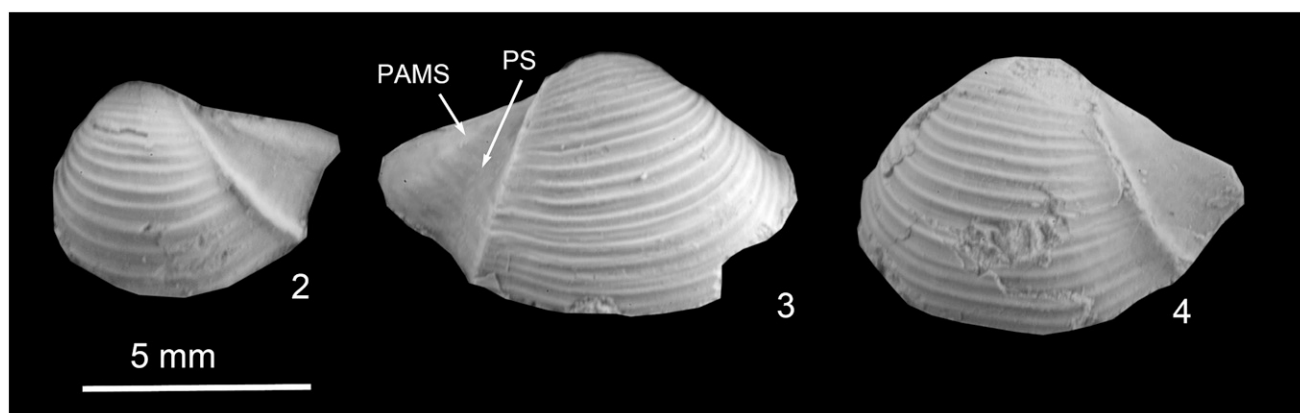


Figure 2–4. *Myonera inouei* new species. **2. Paratype**, left valve, NMNS PM 28358. **3. Holotype**, right valve, NMNS PM 28357; PS, pallial sinus; PAMS, posterior adductor muscle scar. **4. Paratype**, left valve, NMNS PM 28359.

smooth rostrum and many distinct commarginal ribs. However, *Myonera inouei* new species has a sharper ridge between the main disc and the rostrum. Moreover, the point at the end of the ridge is sharp, extending beyond the ventral margin in *M. angularis*.

Myonera inouei new species is also similar to the Recent species *Myonera paucistriata* Dall, the type species of the genus *Myonera*, living in the deep water (166–3806 m) of the western Atlantic from North Carolina to Brazil and Hawaiian Islands (Allen and Morgan, 1981; Oliveira and Absalão, 2009). However, two sharp radial ribs of *M. paucistriata* easily enable us to separate from the new species.

Distribution: Known only from the type locality.

Etymology: Named for Mr. Kiyokazu Inoue in Obihiro City, who collected this species.

DISCUSSION

According to Nishijima's (1964) description and our observations, the ill-sorted conglomerates of Nishijima's Tomikawa Member can be interpreted as submarine debris-flow deposits in upper bathyal depths. The associated bivalve *Parathyasira* species now lives in depths of 50–2000 m (Higo et al., 1999). An associated Paleocene species of *Procardia* possibly inhabited the upper bathyal zone, because *Procardia inouei* Amano, 2019 was described from a Paleocene upper bathyal deposit (Amano, 2019). *Myonera angularis* which, as described above, is very similar to *M. inouei*, lives in depths of 530–4715m. Based on these data, *Myonera inouei* new species possibly lived in upper bathyal depths.

As mentioned above, *Myonera inouei* new species is the oldest-known species of this genus at present. Previously, Goedert (1995) recorded *Myonera* sp. from the Oligocene Makah Formation in Washington State as oldest-known species in the genus. However, as mentioned above, this species actually belongs to *Bathyneera*. This implied that the oldest unequivocal *Myonera*

up to now had been *M. kurosedaniensis* from the lower Miocene Kurosedani Formation. With the discovery of *M. inouei*, the fossil record of *Myonera* has been extended back to the late Selandian.

Some genera of bivalves first appeared in the Paleocene deep-water deposits in eastern Hokkaido (Amano and Jenkins, 2017; Amano et al., 2015, 2016, 2018). These are the tindariid *Tindaria*, the arcid *Bentharca*, the poromyid *Poromya*, the naticid *Neverita*, and the cancellariid *Admete*. As a result of this study, *Myonera* has been added to these genera. Our estimate is supported by the bathyal origin assessment of Cuspidariidae including *Myonera* proposed by Krylova (1989), based on the vertical distribution of the Recent cuspidariid species.

Previously, major evolution was considered to have occurred in shallow marine waters and then to have invaded deep water through geological time (Jablonski et al., 1983; Jablonski and Bottjer, 1991). However, it has recently been suggested that some deep-sea organisms such as corals, echinoderms, and mollusks originated in the deep sea and some have moved to shallow water (Pante et al., 2012; Thuy et al., 2012; Hryniewicz et al., 2017). The above six genera from the Paleocene in eastern Hokkaido support the deep-water origin theory for those organisms. Although many deep-water benthonic foraminifers became extinct at the Paleocene-Eocene Thermal Maximum (PETM) (Kaiho, 1994), some mollusks including the above six genera were able to survive the deep-sea anoxic event at the PETM.

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