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A new Paleocene species of Aporrhaidae (Gastropoda) from eastern Hokkaido, Japan

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Abstract. We describe one new aporrhaid species, *Kangilioptera inouei* sp. nov., from the Paleocene Katsuhira Formation in Urahoro Town, eastern Hokkaido, Japan. This is the first record of a Cenozoic Aporrhaidae (Anchurinae) gastropod in Japan. Occurrences of *Kangilioptera* are confined to Paleocene deposits in western Greenland and Japan. With the addition of the bivalve *Conchocele*, the new find requires a reappraisal of the marine connection through the Bering Strait between Japan and Greenland during the Paleocene.

Key words: Aporrhaidae, Gastropoda, Japan, *Kangilioptera*, Mollusca, Paleocene

Introduction

The family Aporrhaidae first appeared during the Early Jurassic, attained its maximum generic diversity in the Maastrichtian and then decreased after the mass extinction at the end of the Cretaceous (Roy, 1994; Gründel *et al*., 2009). According to Roy (1996), 76% of the family's genera became extinct during the end-Cretaceous mass extinction. Since the Pliocene, only two genera, *Aporrhais* and *Arrhoges*, survived in the Atlantic and Mediterranean regions (Wenz, 1938; Roy, 1994). The extant species of *Aporrhais* and *Arrhoges* are detritus feeders and have a unique ecology. They change seasonally from infaunal to epifaunal (Yonge, 1937; Perron, 1978). They usually live on mud, sand or muddy gravel bottoms at water depths from 10 to 2000 m (Clarke, 1962; Poppe and Goto, 1991).

In the northwestern Pacific region, eighteen aporrhaid species have been recorded from Cretaceous deposits (Yabe and Nagao, 1925, 1928; Nagao, 1932, 1934, 1939; Matsumoto *et al.*, 1965; Kase and Maeda, 1980; Hayami and Kase, 1981; Kase, 1984; Table 1). These species belong to the genera *Anchura*?, *Ceratosiphon*, *Cuphosolenus*?, *Drepanocheilus*, *Harpagodes*?, *Latiala*, *Perissoptera*, *Piettia* and *Tessarolax*. Of these, twelve species are recorded from Lower Cretaceous formations (Barremian and Aptian) and the other six species are from Upper Cretaceous deposits of Cenomanian to Coniacian age.

We have recently collected many specimens of aporrhaid gastropods from Paleocene deposits in eastern Hokkaido. As a result of this examination, a new species is proposed. In this paper, we describe this species and discuss its paleobiogeographical significance.

Mateirals

We have examined 148 aporrhaid specimens from six localities (Loc. nos. 1–6) of the Katsuhira Formation around Katsuhira, Urahoro-cho, eastern Hokkaido (Figure 1). The age of the upper part of this formation near the type locality was assigned to the Selandian based on planktonic foraminifers (Kaiho, 1984). However, Kiminami *et al*. (1978) recorded Danian-type planktonic foraminifers from the overlying and underlying deposits of the Katsuhira Formation. Judging by these data, the age of the Katsuhira Formation near the type locality can be safely assigned to the Paleocene, rather than to the Cretaceous.

The fossil specimens were collected from calcareous concretions (20–40 cm in diameter) with plant debris. Among these, the concretions from Locs. 3 to 5 were found as floats along the Katsuhirazawa River. The aporrhaids occur in association with the taxodont bivalves *Acila*, *Leionucula* and *Neilonella*, small terebratulid brachiopods, and corals.

All specimens are housed at Joetsu University of Education (JUE). The terminology for describing the new species follows Saul and Petit (2001).

Table 1. Cretaceous aporrhaid species in the northwestern Pacific region.

Age	Species	Formation	Region	Data source
Barremian	*Ceratosiphon densestriatus* Kase	Kimigahama Fm.	Choshi, Honshu	Kase and Maeda (1980)
	C. giganteus Kase	Hijochi Fm.	Ofunato, Honshu	Kase (1984)
	Ceratosiphon.	Ishido Fm.	Sanchu, Honshu	Kase (1984)
	Perissoptera elegans Kase	Kimigahama Fm.	Choshi, Honshu	Kase and Maeda (1980)
	P. cf. *elegans* Kase	Ishido Fm.	Sanchu, Honshu	Kase (1984)
	Piettia cretacea Kase	Kimigahama Fm.	Choshi, Honshu	Kase and Maeda (1980)
Aptian	*Ceratosiphon* cf. *ebrayi* (de Loriol)	Tanohata Fm.	Miyako, Honshu	Kase (1984)
	Cuphosolenus? sp. indet.	buried deposit	Taiwan	Matsumoto *et al.* (1965)
	Drepanocheilus elongatodigitatus Nagao	Hiraiga Fm.	Miyako, Honshu	Nagao (1934), Kase (1984)
	Drepanocheilus sp.	Hiraiga Fm.	Miyako, Honshu	Kase (1984)
	Latiala hayamii Kase	Hiraiga Fm.	Miyako, Honshu	Kase (1984)
	Perissoptera aff. *parkinsoni* (Mantell)	Tanohata Fm.	Miyako, Honshu	Kase (1984)
Cenomanian	*Drepanocheilus minimus* Kase	offshore deposit	Kuji, Honshu	Hayami and Kase (1981)
Cenomanian or Turonian	*Anchura*? sp.	Middle Yezo Gp.	Hokkaido	Nagao (1932)
Conacian or Santonian	*Perissoptera*? sp.	Upper Yezo Gp.	Hokkaido	Nagao (1939)
	Tessarolax acutimarginatus Nagao	Upper Yezo Gp.	Hokkaido and Sakhalin	Nagao (1932)
	Tessarolax japonicus Yabe and Nagao	Upper Yezo Gp.	Hokkaido	Yabe and Nagao (1928)
Upper Cretaceous	*Harpagodes*? *sachalinensis* Yabe and Nagao	Jonquiere Gp., Upper Yezo Gp.	Sakhalin	Yabe and Nagao (1925)

Systematic paleontology

Family Aporrhaidae Gray, 1850
Subfamily Anchurinae Kollmann, 2009

Type genus.—*Anchura* Conrad, 1860

Remarks.—Kollmann (2009) proposed Anchurinae consisting of *Anchura*, *Alarimella* Saul, 1998, *Drepanocheilus* Meek, 1864, *Helicaulax* Gabb, 1868, *Pugioptera* Pchelintsev, 1953, *Pseudanchura* Kollmann, 2005 and *Pletzachia* Kollmann, 2009. Although the genus *Kangilioptera* Rosenkrantz, 1970 was not mentioned in the original description of Anchurinae, it can be safely included in this subfamily based on Kollmann's diagnosis.

Genus ***Kangilioptera*** Rosenkrantz, 1970

Type species.—*Anchura* (*Kangilioptera*) *ravni* Rosenkrantz, 1970 (by monotypy). Paleocene Kangilia Formation (*Propeamussium* Member) in western Greenland.

Remarks.—*Kangilioptera* is characterized by one posterior labral digitation extending from the uppermost keel of the last whorl, a lobe at the anterior edge of the wing, three keels on the last whorl and many axial ribs on the spire whorls. *Drepanocheilus* Meek, 1864 is most similar to this genus, but differs from *Kangilioptera* in having no projection at the anterior edge of the wing (see Kiel and Bandel, 2002). *Anchura* Conrad, 1860 is another similar genus to *Kangilioptera*. However, *Anchura* differs from *Kangilioptera* by having only one keel and some axial ribs on the last whorl. *Struthioptera* Finlay and Marwick, 1937, belonging to Struthiopterinae Zinsmeister and Griffin, 1995, is somewhat similar to *Kangilioptera* in having one wing, some axial ribs and many fine spiral striations. However, *Struthioptera* differs from *Kangilioptera* by having two keels, some axial ribs on the last whorl and no anterior lobe on the wing (see also Stilwell, 2003).

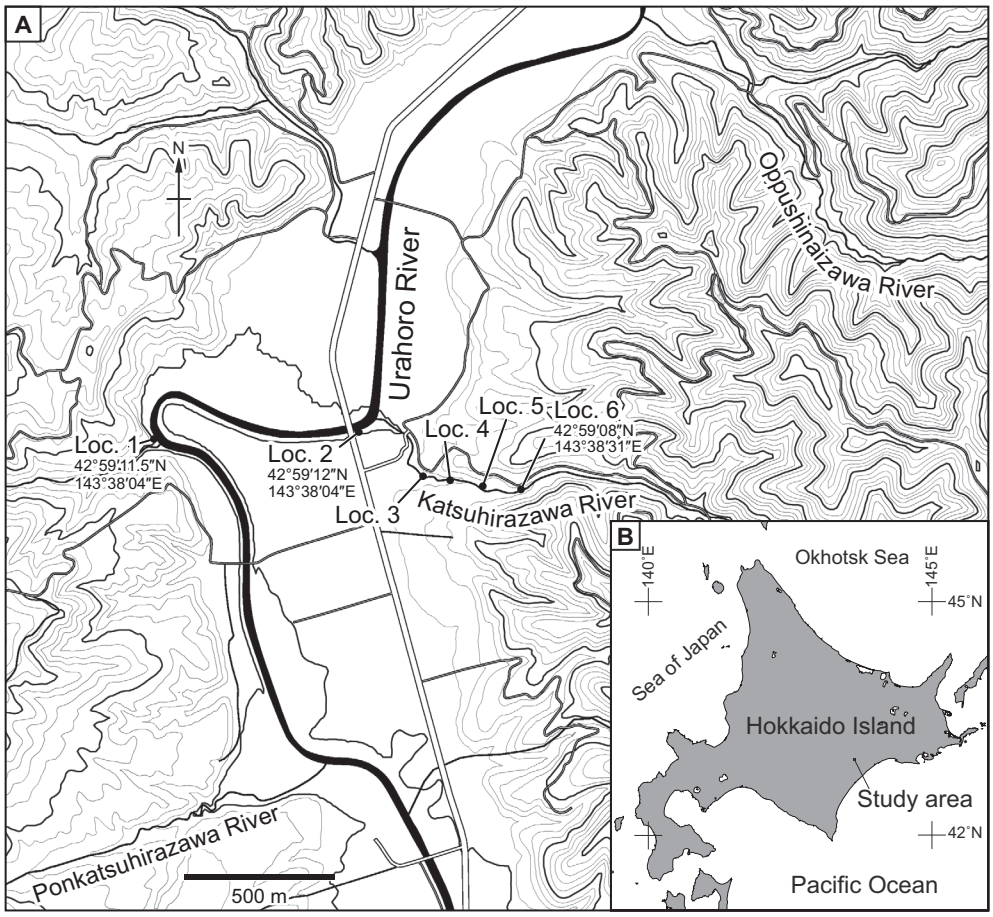

Figure 1. Localities of *Kangilioptera inouei* sp. nov.

Kangilioptera inouei Amano and Jenkins, sp. nov.
[Japanese name: Urahoro-momijisodebora]

Figure 2.1–2.9

Etymology.—Named for Kiyokazu Inoue, who collected and offered the type specimens.

Type material.—Holotype, JUE no. 15915 (Figure 2.5a–d); paratypes, JUE no. 15916 (Figure 2.8), 15917 (Figure 2.9).

Type locality.—Bank of Urahoro River 1.2 km north of the mouth of the Ponkatsuhirazawa River (Loc. 1); Katsuhira Formation.

Dimensions.—See Table 2.

Diagnosis.—Medium-sized aporrhaid with many fine spiral striae, three keels on last whorl including base and fifteen to nineteen axial ribs on spire whorls. Posterior labral digitation prominent, short and with lobe at anterior edge of wing in some specimens.

Description.—Medium-sized shell, up to 26.1 mm high, turriform; protoconch missing; teleoconch comprising eight whorls. Suture weakly impressed. Last whorl occupying 46% of shell height with many fine spiral striae and three keels; uppermost keel at shoulder, bearing small nodes, extending to posterior labral digitation; middle keel weaker than uppermost one, situated at transition to base; lowest keel relatively weak on base. Uppermost keel at about mid-whorl on spire whorls, forming periphery, but absent from earliest spire whorl (Figure 2.5b); middle and lowest keels absent from spire whorls. Penultimate whorl with fine spiral striae and 15 to 19 sigmoidal axial ribs on blunt keel. Lower third of whorl sculptured by fine spiral striae and 19 sigmoidal axial ribs with narrow interspaces. Posterior labral digitation rather short, prominent, without lobe at anterior end of wing in most specimens. Some specimens, such as paratype (JUE no. 15916), with wide lobe at anterior end of wing (Figure 2.8). Inner lip covered with rather thin callus reaching to top of penultimate whorl. Rostrum short and straight.

Comparisons.—The present new species can be distin-

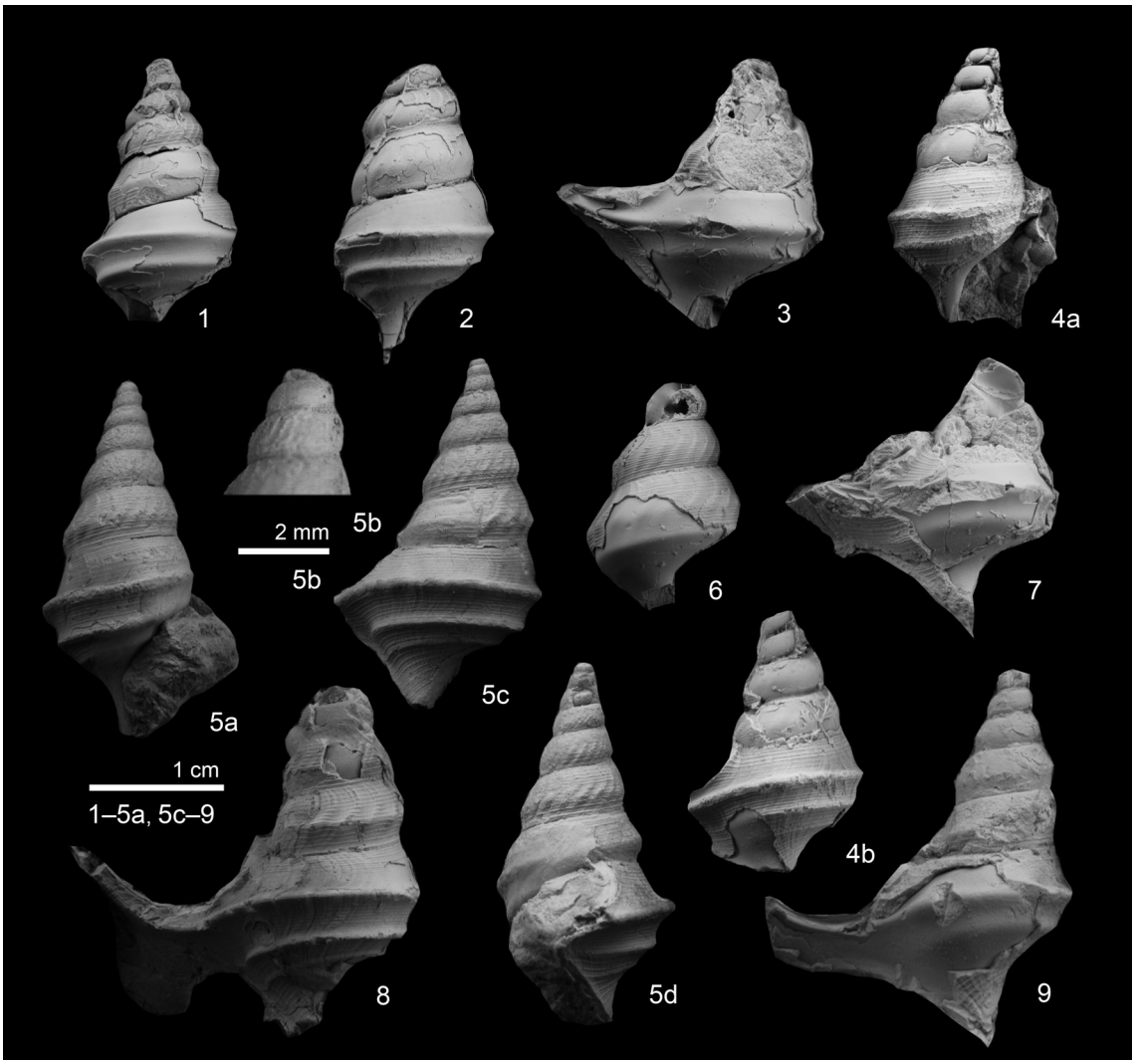

Figure 2. *Kangilioptera inouei* sp. nov., Paleocene Katsuhira Formation, Japan. **1,** JUE no. 15921-1, abapertural view, Loc. 5; **2,** JUE no. 15921-3, abapertural view, Loc. 5; **3,** JUE no. 15921-2, abapertural view, Loc. 5; **4,** JUE no. 15919-1; 4a, apertural view; 4b, abapertural view, Loc. 3; **5,** holotype, JUE no. 15915; 5a, apertural view; 5b, early whorls; 5c, abapertural view; 5d, side view, Loc. 1; **6,** JUE no. 15919-2, abapertural view, Loc. 3; **7,** JUE no. 15920-1, abapertural view, Loc. 4; **8,** paratype, JUE no. 15916, abapertural view, Loc. 1; **9,** paratype, JUE no. 15917, abapertural view, Loc. 1.

guished from the type species of the genus, *Kangilioptera ravni* (Rosenkrantz, 1970), by having a smaller shell, a shorter labral digitation and rostrum, and a rather broad lobe at the anterior edge of the wing in some specimens. *Kangilioptera inouei* sp. nov. is also similar to some specimens of *Drepanocheilus pervetus* (Stanton, 1920). Specimens lacking a wing from the Paleocene Mount Moore Formation in Ellesmere Island described by Marincovich and Zinsmeister (1991, Figure 4.22, 4.23) resemble *K. inouei* sp. nov. in having three keels of which the uppermost one is provided with nodes and in lacking axial ribs on the last whorl. However, the latter species differs from *K. inouei* sp. nov. by lacking a posterior digitation on the wing and by having a very thick outer lip.

Stratigraphic and geographic range.—Six localities of the Paleocene Katsuhira Formation near the type locality.

Paleobiogeography and evolutionary history of *Kangilioptera*

This is the first record of an aporrhaid from Cenozoic deposits in Japan. Cenozoic aporrhaids are known from Europe, Egypt, the Atlantic side of the United States, western Greenland, Ellesmere Island (Canada), the

Table 2. Measurements of *Kangilioptera inouei* sp. nov. specimens. 1, number of whorls; 2, diameter without wing; 3, number of keels on penultimate whorl; 4, number of keels on last whorl; 5, number of axial ribs on penultimate whorl; 6, number of axial ribs on last whorl.

Specimens	Type	NW[1]	Height (mm)	Diameter (mm)[2]	NKP[3]	NKB[4]	NAP[5]	NAB[6]	Loc.
JUE no. 15915	Holotype	8	26.1	14.8	1	3	15	0	1
JUE no. 15916	Paratype	4+	24.1+	–	0	3	6+	0	1
JUE no. 15917	Paratype	6+	25.4+	–	0	3	–	0	1
JUE no. 15918	Topotype	7+	22.4+	12.0	0	3	–	–	1
JUE no. 15919-1		5+	18.1+	12.5	0	3	–	0	3
JUE no. 15919-2		3+	18.1+	11.7	0	–	19	–	3
JUE no. 15920-1		3+	19.4+	–	–	3	–	–	4
JUE no. 15920-2		3+	16.7+	–	0	3	–	0	4
JUE no. 15921-1		5+	19.1+	11.9	0	3	–	0	5
JUE no. 15921-2		3+	18.3+	–	0	3	–	0	5
JUE no. 15921-3		4+	23.2+	11.8	0	3	16+	0	5
JUE no. 15921-4		6+	19.6+	11.6	1?	3	15+	0	5

Pacific side of North America, Peru, Chile, Argentina, Australia, New Zealand and Antarctica (Olsson, 1931; Wenz, 1938; Rosenkrantz, 1970; Squires and Demetrion, 1990; Marincovich and Zinsmeister, 1991; Zinsmeister and Griffin, 1995; Squires and Saul, 2001). On the Pacific side of North America, five Paleocene and one Eocene aporrhaid species have been recorded (Squires and Demetrion, 1990; Squires and Saul, 2001). The present Paleocene record from Hokkaido is the only one from the northwestern Pacific.

Based on morphological evidence, *Kangilioptera* possibly was derived from the Cretaceous genus *Drepanocheilus*. Occurrences of *Kangilioptera*, including this new species, are restricted to Paleocene rocks in western Greenland and Hokkaido. From the Danian deposits in the western part of Greenland, *Conchocele* aff. *conradi* (Rosenkrantz) has been recorded (Rosenkrantz, 1970). *Conchocele* was first recorded in the northern Pacific in Eocene rocks (e.g. Yabe and Nomura, 1925; Slodkewitsch, 1938; Krishtofovich, 1936, 1947, 1964; Kanno, 1971; Moore, 1988). *Conchocele* possibly migrated from the Arctic Ocean to the northern Pacific by the Eocene. There is no record of *Conchocele* in the Atlantic Ocean and Tethys Ocean regions (Chavan, 1969), although it does occur in Paleocene–Eocene rocks of New Zealand. The shortest pathway of geographical spread of this genus possibly was through the Bering Strait. According to Hopkins and Marincovich (1984) and Marincovich *et al.* (1990), the Arctic Ocean was isolated during latest Cretaceous to Paleocene time. However, based on the distribution of *Kangilioptera* and *Conchocele*, it is necessary to consider the possibility of a marine connection through the Bering Strait between the Arctic Ocean and the northern Pacific Ocean during the Paleocene.

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