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A new and ontogenetically younger specimen of *Numataphocoena yamashitai* from the upper part of the Horokaoshirarika Formation (lower Pliocene), Numata, Hokkaido, Japan

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Abstract. A new periotic of *Numataphocoena yamashitai* from the upper part of the Horokaoshirarika Formation (lower Pliocene), Numata, Hokkaido, Japan shows younger ontogenetic features in comparison to the matured holotype (NFL 7). The referred specimen of *N. yamashitai* is smaller (approximately 90% in size) than the physically and sexually matured holotype periotic. The holotype (NFL 7) and referred specimen (NFL 2617) show several differences owing to ontogenetic changes, such as: the holotype (NFL 7) has a more strongly swollen medial part of the anterior process, blunt anterior keel, rounded anterodorsal angle, deeper and clearer anterior incisure, more rounded pars cochlearis, deeper and narrower hiatus epitympanicus rather than a flat area, longer posterior process with an extra edge posterolaterally. *N. yamashitai* differs from other fossil phocoenids in having a narrower and sharper anterior part of the internal acoustic meatus and a robust anterior process. *Haborophocoena toyoshimai* similarly has a relatively narrow internal acoustic meatus and a robust anterior process, compared with other fossil phocoenids. Between *N. yamashitai* and *H. toyoshimai*, *N. yamashitai* has a narrower internal acoustic meatus and a more robust anterior process. These similarities imply a close relationship between *Numataphocoena* and *Haborophocoena*. The new specimen provides diagnostic features and insight into ontogenetic variation of *N. yamashitai*.

Key words: fossil, ontogeny, periotic, Phocoenidae

Introduction

The holotype of *Numataphocoena yamashitai*, a primitive fossil phocoenid, was found at an outcrop of the upper part of the Horokaoshirarika Formation (upper Miocene to lowest Pliocene) at the riverbed of the Horonitachibetsu River, Numata, Hokkaido, Japan in 1985 by Shigaru Yamashita. *N. yamashitai* was later described as a new genus and species by Ichishima and Kimura (2000) and identified as a physically and sexually mature individual, based on closed and firm epiphyseal sutures of the vertebrae, ulna and radius. Referred materials of *N. yamashitai* have never been described or reported. A new periotic is here described and identified as *N. yamashitai* from the upper part of the Horokaoshirarika Formation, 1 km upstream from the type locality of *N. yamashitai* along the Horonitachibetsu River. The periotic was found with an otariid fossil pinniped, NFL 10 (Yamashita and Kimura, 1990), from the same area. The periotic shows smaller dimensions, which probably reflects the younger ontogenetic stage of the referred individual. This is the first referred specimen of this species.

Institutional abbreviations.—NFL = Numata Fossil Museum, Hokkaido, Japan, NMNS = National Museum of Nature and Science, Tsukuba, Japan, SMAC = Sapporo Museum Activity Center, Sapporo, Japan.

Systematic paleontology

Order Cetacea Brisson, 1762
Unranked taxon Neoceti Fordyce and de Muizon, 2001
Order Odontoceti Flower, 1867
Family Phocoenidae Gray, 1825

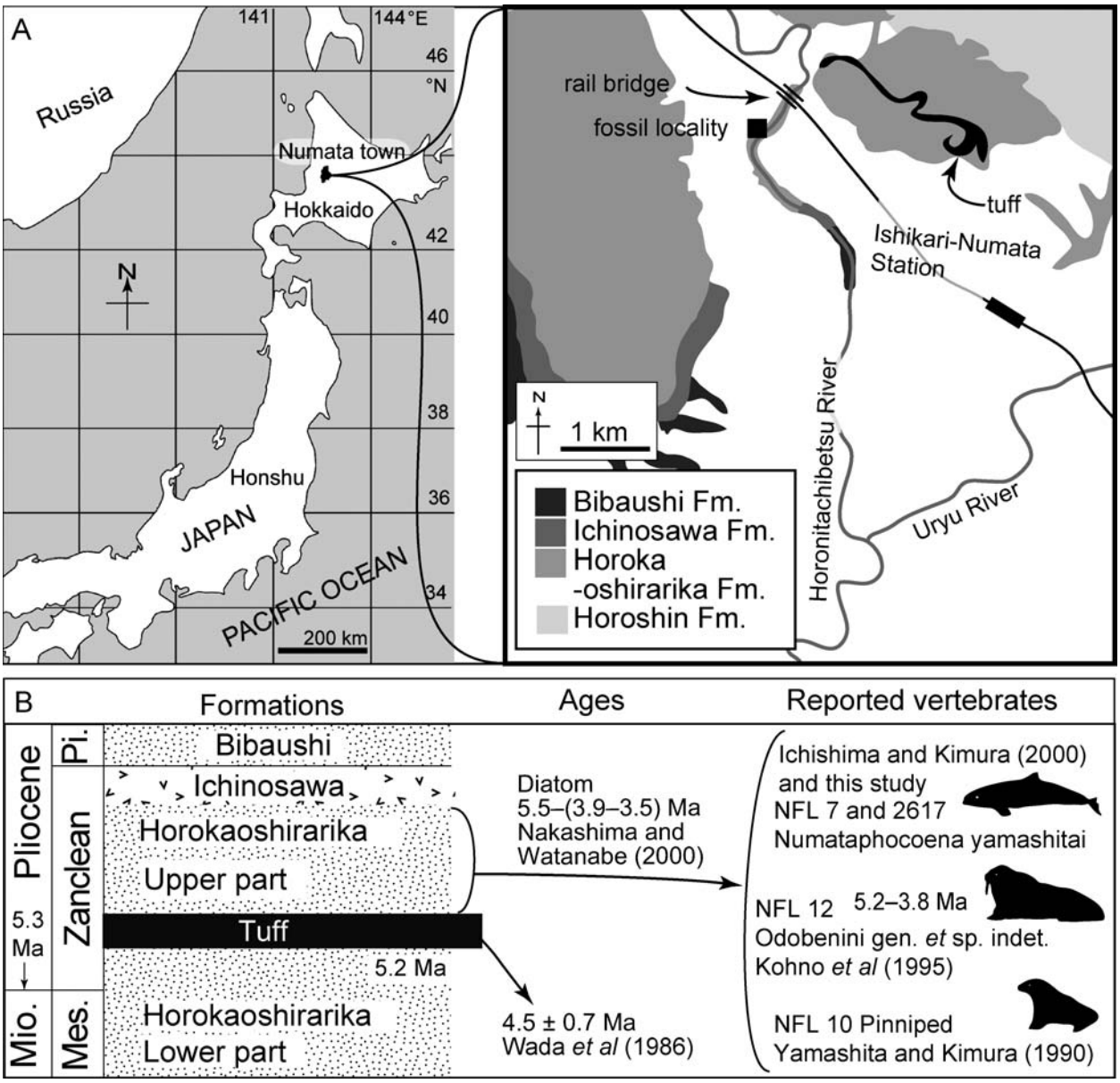

Figure 1. Locality maps (A) and stratigraphic sections of the locality based on previous studies which are mentioned in the text (B). Left side of figure A is from Tanaka and Kohno (2015).

Genus ***Numataphocoena*** Ichishima and Kimura, 2000

Type species.—*Numataphocoena yamashitai* Ichishima and Kimura, 2000.

Numataphocoena yamashitai Ichishima and Kimura, 2000

Figures 2, 3

Material.—NFL 2617, isolated right periotic, collected by Masanobu Kato, Takayuki Tanaka and Tadashi Seto in August 1986.

Remarks.—NFL 2617 is identified as *Numataphocoena yamashitai*, because *N. yamashitai* can be distinguished from other phocoenids by having a massive and robust anterior process and a narrower and sharper anterior part of the internal acoustic meatus, and by having a flat area around the aperture for the vestibular aqueduct.

Locality.—NFL 2617 was dug up with a fossil pinniped, NFL 10 from the riverbed of the Horonitachibetsu

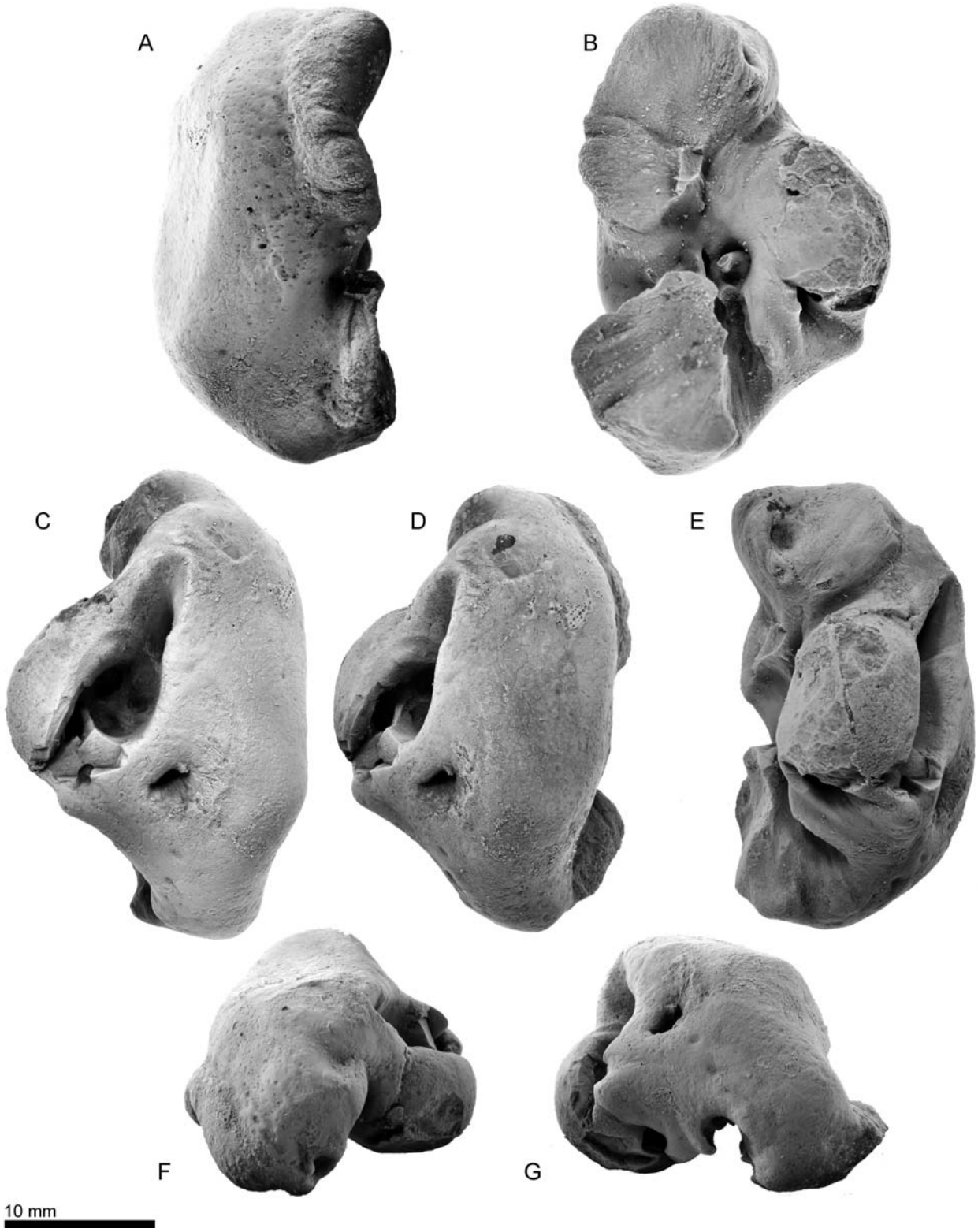

Figure 2. Right periotic of *Numataphocoena yamashitai* Ichishima and Kimura, 2000, NFL 2617. **A,** lateral view; **B,** ventral view; **C,** dorsomedial view; **D,** dorsal view; **E,** medial view; **F,** anterior view; **G,** posterior view.

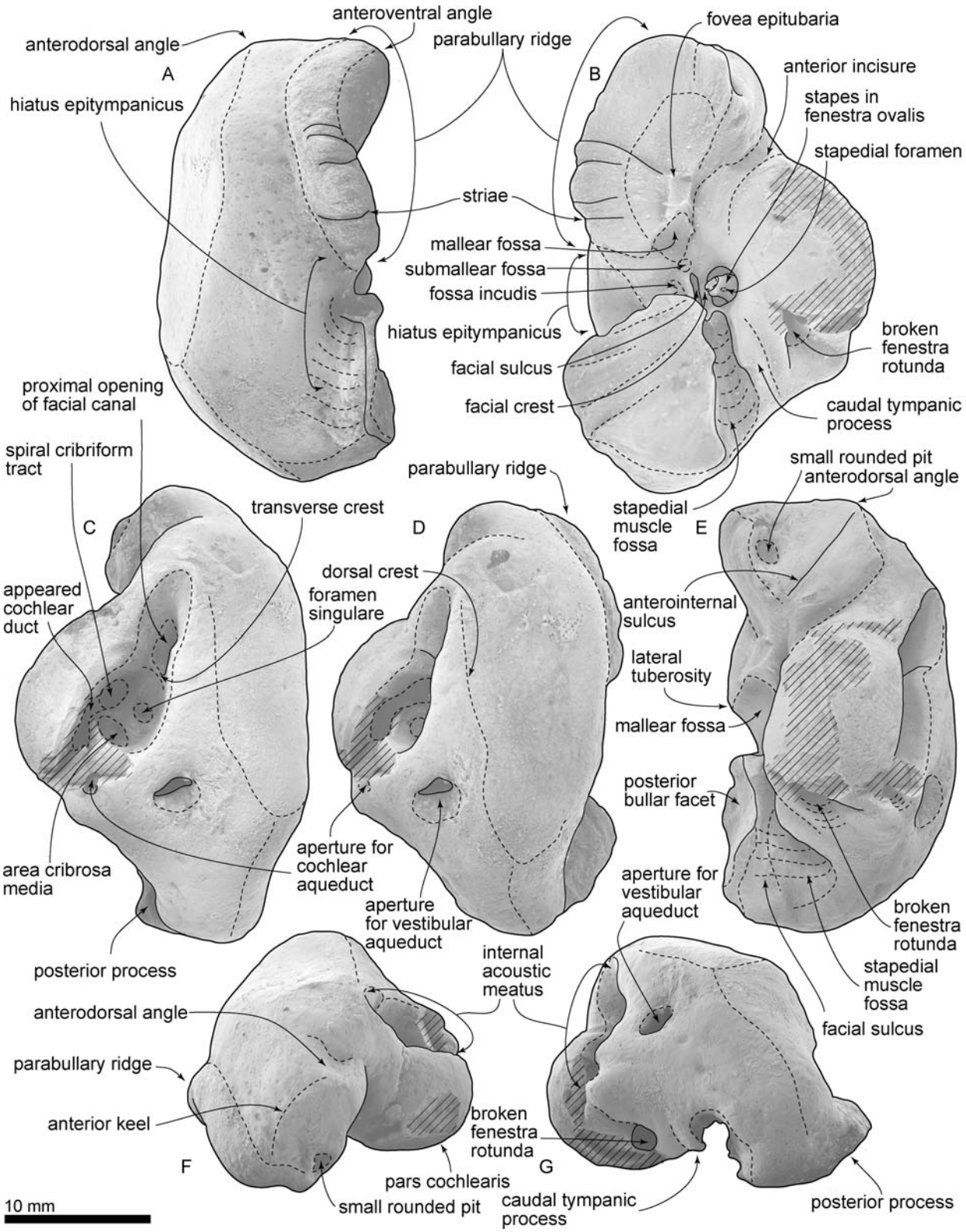

Figure 3. Key features of right periotic in Figure 2, *Numataphocoena yamashitai* Ichishima and Kimura, 2000, NFL 2617. **A,** lateral view; **B,** ventral view; **C,** dorsomedial view; **D,** dorsal view; **E,** medial view; **F,** anterior view; **G,** posterior view.

Table 1. Measurements in mm of right periotics (NFL 2617 and holotype NFL 7) of *Numataphocoena yamashitai* Ichishima and Kimura, 2000. Dimensions follow Fordyce (2002), Perrin (1975) and Kasuya (1973). Measurements are rounded to the nearest 0.5 mm. For skull and mandible, distances are either horizontal or vertical.

Periotic	NFL 2617	NFL 7
maximum anteroposterior length from anterior apex of anterior process to apex of posterior process	30.5	33.6
maximum anteroposterior length parallel to dorsal margin	30.3	33.8
maximum dorsoventral depth anterior process perpendicular to axis of periotic	16.1	15.8
length of anterior process from anterior apex to level of posterior of mallear fossa	15.6	15.6
length of anterior process from anterior apex of anterior process to level of anterior of pars cochlearis in notch immediately lateral to fine ridge	8.5	7.2
dorsoventral depth at fovea epitubaria	10.5	11.6
length facet on posterior process point to point	10.6	12.2
maximum width of anterior process at base	11.7	13.1
approximate anteroposterior length of pars cochlearis	16.6	18.2
approximate transverse width of pars cochlearis from internal edge to fenestra ovalis	8.6	9.3
transverse width of periotic, internal face of pars cochlearis to apex of lateral tuberosity	10.7	10.9
length of posterior process of periotic	10.5	12.6
length of posterior process parallel to posterior profile/ steeply acute to long axis of body	11.4	13.1

River, upper Miocene to lowest Pliocene, upper part of the Horokaoshirarika Formation, Numata, Hokkaido, Japan (Yamashita and Kimura, 1990). These specimens were collected by Shigeru Yamashita, Masaichi Kimura, Numata Fossil Laboratory (former name of Numata Fossil Museum) and the Numata Town Board of Education. The site is 91 m south of a rail bridge of the Japan Railroad (JR) just next to Yutaka Bridge, which is about 3 km northwest from Ishikari-Numata Station (Figure 1; latitude 43°49′55″N, longitude 141°54′20″E).

Horizon and age.—The Miocene–Pliocene sedimentary sequence at Numata, Hokkaido includes about 200 m and 500 m thickness of the upper and lower parts of the Horokaoshirarika Formation, respectively (Watanabe and Yoshida, 1995). A thin tuff layer separates the upper and lower parts of the Horokaoshirarika Formation (Kobayashi *et al*., 1969). Fission track method provided an age for the tuff of 4.5 ± 0.7 Ma (Wada *et al*., 1986). Above the Horokaoshirarika Formation, the Ichinosawa and Bibaushi formations lie in the lower stream of the Horonitachibetsu River. The Horoshin Formation is exposed 2 km upstream from this locality. NFL 2617 was collected *in situ* from the upper part of the Horokaoshirarika Formation. NFL 2617 has been cleaned and has no matrix. The original horizon of NFL 10, which is the same as that of NFL 2617, is the upper part of the Horokaoshirarika Formation (Furusawa *et al*., 1993). From the upper part of the Horokaoshirarika Formation, three vertebrates, the type skeleton of *Numataphocoena yamashitai*, a tusk of a walrus (Odobenini) and an otariid skeleton have been reported (Ichishima and Kimura, 2000; Kohno *et al*., 1995; Yamashita and Kimura, 1990). The age of the upper part of the Horokaoshirarika Formation is about the age of the tuff layer, 4.5 ± 0.7 Ma. Diatoms from the upper part of the Horokaoshirarika Formation correspond to the *Thalassiosira oestrupii* zone, which shows its age as 5.5 to 3.5 Ma, the late Miocene to the earliest Pliocene (Nakashima and Watanabe, 2000). Following the diatom zonation the age of the upper part of the Horokaoshirarika Formation is about 5.5 to 3.5 Ma, the late Miocene to the earliest Pliocene.

General description

Periotic.—Morphological terminology follows Mead and Fordyce (2009). The periotic (Figures 2, 3 and Table 1) has a short and wide anterior process, skewed medially, and a globe-like pars cochlearis, which is about twice as long as the anterior process. The posterior process is short.

The anterior process is robust, with a prominent anterodorsal angle and keel. Laterally, the parabullary ridge is swollen and bears small striae. The fovea epitubaria for the accessory ossicle is deeply depressed and

Figure 4. Right periotic of *Numataphocoena yamashitai* Ichishima and Kimura, 2000, NFL 7, holotype. **A,** lateral view; **B,** ventral view; **C,** dorsomedial view; **D,** dorsal view; **E,** medial view; **F,** anterior view; **G,** posterior view.

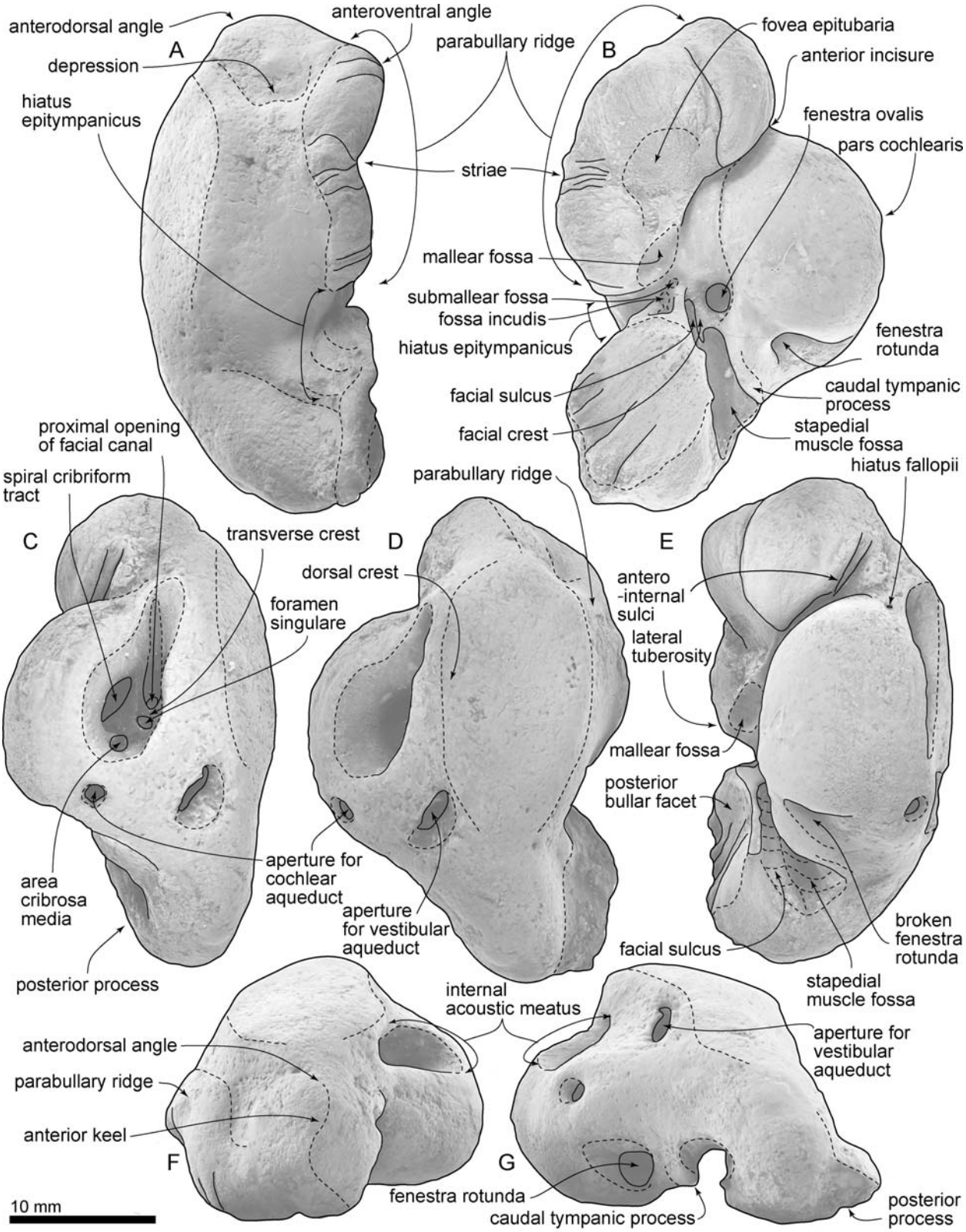

Figure 5. Key features of right periotic in Figure 4, *Numataphocoena yamashitai* Ichishima and Kimura, 2000, NFL 7, holotype. **A,** lateral view; **B,** ventral view; **C,** dorsomedial view; **D,** dorsal view; **E,** medial view; **F,** anterior view; **G,** posterior view.

forms an angle on the parabullary ridge in lateral view. On the anteromedial surface of the anterior process, the anterointernal sulcus runs between the fovea epitubaria and anterodorsal angle. On the holotype, NFL 7 (Figures 4, 5), there are two anterointernal sulci. There is a small rounded pit (about 1 mm in diameter) only on NFL 2617, just anterior to the anterointernal sulcus. The anterior incisure is shallow anteriorly and runs slightly posterior to the anterodorsal angle, deepening posteriorly.

The pars cochlearis is hemispherical ventrally, transversely compressed and anteroposteriorly elongate. A tiny rounded foramen for the hiatus fallopii is visible slightly medial to the anterior edge of the internal acoustic meatus, only on the holotype, NFL 7 (around 0.5 mm in diameter), but is not visible on NFL 2617 because of damage. The anteroposteriorly long triangular internal auditory meatus (maximum length = 12.0 mm, 4.1 mm wide) opens on the center dorsally. The meatus contains four structures: 1, the proximal opening of the facial canal, which is deep, anteroposteriorly long and oval (about 1 mm in diameter); 2, the foramen singulare, which is circular and smaller (about 0.1 mm in diameter); 3, the spiral cribriform tract, which is located anteromedial to the foramen singulare; 4, the area cribrosa media, which is a shallow fossa, is located at the posterior rim of the internal acoustic meatus. A thin transverse ridge separates the large and rounded proximal opening for the facial canal from the smaller foramen singulare. A transverse crest separates the opening of the facial canal and foramen singulare and the spiral cribriform tract and area cribrosa media (broken). The anterior margin of the fenestra rotunda is damaged, but it appears to have been 0.7 mm in transverse diameter. The fenestra rotunda opens posterodorsally. The aperture for the vestibular aqueduct is transversely long (2 mm in maximum diameter) and semi-crescentic. The aperture for the cochlear aqueduct shows broken margins, but is circular and much smaller than the vestibular aqueduct (0.4 mm in diameter).

On the body of the periotic, ventrally, the mallear fossa is a shallow and anteroposteriorly long square (5 mm long and 3 mm wide). The lateral tuberosity is swollen both laterally and ventrally, and continues with the parabullary ridge. The anterolateral end of the parabullary ridge forms the anteroventral angle. The hiatus epitympanicus is narrow, bears a rounded lateral margin, and is situated posterior to the lateral tuberosity. Just between the mallear fossa and posterior process, there are two tiny deep pits, the submallear fossa anteriorly and the fossa incudis posteriorly. The facial crest is thick and separates the fossa incudis and ventral opening of the facial canal. The facial canal is deep and continues to the deep facial sulcus, which widens towards the stapedial muscle fossa posteriorly. Between the facial sulcus and stapedial muscle fossa, there is no clear border. The fenestra ovalis is large (2 mm in diameter) and excavates the pars cochlearis medially. The stapes is *in situ* (see below).

The short posterior process has a thin anterior margin. The bullar facet is weakly depressed with multiple weak ridges. The dorsal surface of the periotic has a developed dorsal angle at the level of the aperture for the vestibular aqueduct.

Stapes.—The right stapes is preserved *in situ*. A small and deep pit on the posteromedial surface presumably represents the vestigial stapedial foramen; the ventral section is smooth (1.3 mm in diameter).

Discussion

Comparison among other fossil Phocoenidae.—The two periotics of *Numataphocoena yamashitai* show shared and diagnostic features, which are discussed here. The reported fossil Miocene and Pliocene phocoenids are listed in Table 2 and compared with *N. yamashitai*.

Numataphocoena yamashitai differs from other phocoenids having a narrower and sharper anterior part of the internal acoustic meatus and a robust anterior process. All other fossil phocoenids have a rounded internal acoustic meatus and also a slender anterior process, except for *Haborophocoena toyoshimai* and *Salumiphocoena stocktoni*. *S. stocktoni* shares a narrow internal acoustic meatus with *N. yamashitai*, but lacks a robust anterior process. *H. toyoshimai* similarly has a relatively narrow internal acoustic meatus and robust anterior process compared with other fossil phocoenids, but they are narrower and more robust, respectively, on *N. yamashitai*. These similarities imply close relationships between *Numataphocoena* and *Haborophocoena*. *N. yamashitai* has never been included in a phylogenetic analysis so far.

Comparison between the referred specimen NFL 2617 and the holotype of Numataphocoena yamashitai, *NFL 7*.—These two periotics share features as discussed above, but differ in size and also some morphological conditions. NFL 7, the holotype of *N. yamashitai*, which has a 10% larger periotic, was identified as a physically and sexually mature individual, based on the closed and firm epiphyseal suture of the vertebrae, ulna and radius (Ichishima and Kimura, 2000). NFL2617 is the first referred specimen of *N. yamashitai* and was recovered from the same stratigraphic unit (upper part of the Horokaoshirarika Formation) at a nearby locality, so morphological differences may simply reflect ontogenetic differences with the holotype. Ontogenetic variation among the Delphinoidea has been discussed by Kasuya (1973). The study examined one phocoenid species, *Neophocaena phocaenoides*, and found that the

Table 2. List of reported Miocene/Pliocene phocoenids.

Scientific name	Age	Formation	Locality	Publication	periotics
Pterophocaena nishinoi	late Miocene	Wakkanai Formation	Japan	Murakami *et al*., 2012a	preserved
Miophocaena nishinoi	late Miocene	Koetoi Formation	Japan	Murakami *et al*., 2012b	preserved
Australithax intermedia	late Miocene	Pisco Formation	Peru	de Muizon, 1986	preserved
Lomacetus ginsburgi	late Miocene	Pisco Formation	Peru	de Muizon, 1988	preserved
Piscolithax boreios	latest Miocene	Almejas Formation	Mexico	Barnes, 1984	preserved
Piscolithax tedfordi	latest Miocene	Almejas Formation	Mexico	Barnes, 1984	preserved
Piscolithax longirostris	latest Miocene	Almejas Formation	Mexico	de Muizon, 1983	preserved
Salumiphocaena stocktoni	late Miocene	Monterey Formation	California	Barnes, 1985; Wilson, 1973	preserved
OU 12087	late Miocene	–	New Zealand	Fordyce, 1989	preserved
Archaeophocaena teshioensis	late Miocene	Koetoi Formation	Japan	Murakami *et al*., 2012b	not preserved
NMNS-PV19736	late Miocene	Koetoi Formation	Japan	Tomida and Kohno, 1992	not preserved
NMV 5	late Miocene	Koetoi Formation	Japan	Murakami *et al*., 2015	not preserved
Haborophocoena toyoshimai	latest Miocene to early Pliocene	Mochikubetsu Formations	Japan	Ichishima and Kimura, 2005, 2013	preserved
Haborophocoena minutus	early Pliocene	Embetsu Formation	Japan	Ichishima and Kimura, 2009	not preserved
Numataphocoena yamashitai	early Pliocene	Horokaoshirarika Formation	Japan	Ichishima and Kimura, 2000 and this study	preserved
Septemtriocetus boesselaersi	early late Pliocene	Lillo Formation	Belgium	Lambert, 2008	not preserved
Semirostrum ceruttii	late Pliocene	San Diego Formation	California	Racicot *et al*., 2014	preserved
Brabocetus gigaseorum	Pliocene	Kattendijk Formation	Belgium	Colpaert *et al*., 2015	not preserved

length of the posterior process (relative to the length of the periotic) increased during growth.

For comparison between ontogenetically different *Numataphocoena yamashitai*, NFL 7 and 2617, five individuals of the modern porpoise, *Phocoena phocoena* were examined. It is supposed that the youngest individual among the five is NFL 2619 (2.5 mm maximum length). SMAC 1263 (2.7 mm) and SMAC 2878 (2.9 mm) are juveniles, but more developed compare with NFL 2617. Two supposed adult periotics, TK 84 (in Kasuya, 1973, pl. 12, figs. 10–18) and one in the B. T. Walter Collection (in Wilson, 1973; Fig. 6g–h) are used for comparison.

The differences listed below might be ontogenetic variations, which are seen among the modern periotics above. Compare to ontogenetically younger individuals, adults have a swollen medial surface of the anterior processes; more rounded anterodorsal angles; deeper anterior incisures: more rounded and larger pars cochlearis; longer posterior process.

These ontogenetic variations on the periotic are seen between the two *N. yamashitai*. The holotype (NFL 7) has a more strongly swollen medial surface of the anterior process, which shows a blunt anterior keel anteriorly. Related with the swollen structure, the anterodorsal angle is more rounded, and the anterior incisure is deeper and clearer (the angles between the anterior process and anterior surface of the pars cochlearis are 120 and 102 degrees, NFL 2617 and 7 respectively). The pars cochlearis is larger and more rounded on the holotype (NFL 7). The hiatus epitympanicus is a V-shaped notch on the holotype, but is a flat area on the referred specimen. The holotype's posterior process is longer with an extra edge posterolaterally.

Previously, three periotic features were used to diagnose *N. yamashitai*. One of the three, having a swollen and rounded cochlear portion, relates to ontogeny. Another diagnostic character, having a massive and robust anterior process (length/width are 0.62 and 0.63) can be useful for identify *N. yamashitai*, even if differ-

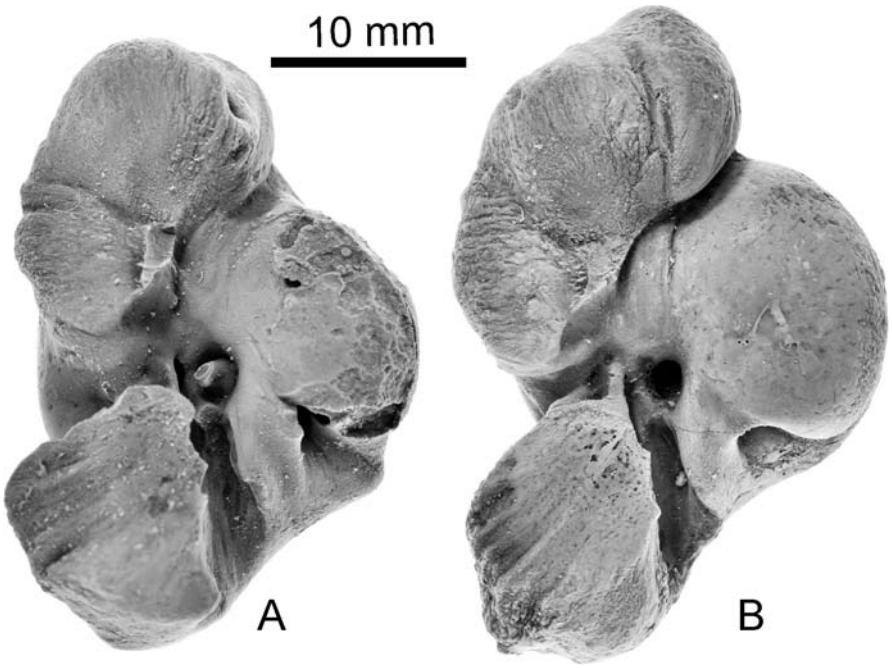

Figure 6. Comparative figure of the periotics in ventral view of *Numataphocoena yamashitai* Ichishima and Kimura, 2000. **A,** NFL 2617; **B,** NFL 7 (holotype).

ences can be seen between the matured holotype (NFL 7) and the immature referred specimens (NFL 2617). No other phocoenid has such a robust anterior process.

Conclusion

The new periotic described herein is assigned to *Numataphocoena yamashitai* from the Horonitachibetsu River, the lower Pliocene (about 3.5 to 5.5 Ma, the upper part of the Horokaoshirarika Formation, Numata, Hokkaido, Japan), which shows a robust anterior process and very narrow anterior margin of the internal acoustic meatus. The specimen is 90% the size of the holotype of *N. yamashitai* (assumed to be a physically and sexually matured individual). More specimens will provide further diagnostic features and insight into ontogenetic variation of *N. yamashitai*.

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