HOKKAIDO UNIVERSITY

Title	A short report of the first record of an Odontoceti (toothed whale) from the Korematsu Formation, Bihoku Group (latest Early to earliest Middle Miocene) in Japan
Author(s)	Tanaka, Yoshihiro; Yamaoka, Takanobu; Ohzawa, Hitoshi et al.
Citation	Paleontological Research, 30, 17-27 https://doi.org/10.2517/prpsj.250023
Issue Date	2026
Doc URL	https://hdl.handle.net/2115/100339
Type	journal article
File Information	Paleontological Research_30_250023.pdf

Hokkaido University Collection of Scholarly and Academic Papers : HUSCAP

PR
https://www.jstage.jst.go.jp/browse/prpsj
DOI: https://doi.org/10.2517/prpsj.250023
Paleontological Research, vol. 30, p. 17–27, 2026
Article

A short report of the first record of an Odontoceti (toothed whale) from the Korematsu Formation, Bihoku Group (latest Early to earliest Middle Miocene) in Japan

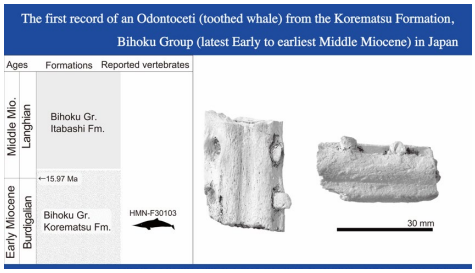
Yoshihiro TANAKA[1,2,3]*, Takanobu YAMAOKA[4], Hitoshi OHZAWA[4], Tomomi KIYOSHI[4]

[1]*Sapporo Museum Activity Center, 5-15-1-6 Hiragishi, Toyohira-ku, Sapporo, Hokkaido 062-0935, Japan*
[2]*Division of Academic Resources and Specimens, Hokkaido University Museum, Kita 10, Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan*
[3]*Numata Fossil Museum, 2-7-49 Minami 1, Numata, Hokkaido 078-2225, Japan*
[4]*Shobara Kaseki Shudankai, Hiwa Museum for Natural History, 1119-1 Hiwa, Hiwa Town, Shobara, Hiroshima 727-0301, Japan*

[Received April 9, 2025; Revised manuscript accepted November 11, 2025; Published online March 12, 2026]

ABSTRACT

For toothed whales, the Early Miocene was a time of transition between archaic and modern clades. In Japan, there are horizons that include whale fossils from the Early to early Middle Miocene, such as the Ichishi Group in Mie, the Mizunami and Iwamura groups in Gifu, the Morozaki Group in Aichi, and some formations in Akita, Iwate and Hokkaido. The Bihoku Group in Hiroshima has abundant baleen whale (Mysticeti) fossils, but only one possible toothed whale (Odontoceti) fossil exists. Here, we report the first unambiguous fossil record of Odontoceti from the Korematsu Formation of the Bihoku Group (latest Early to earliest Middle Miocene), a pair of fused middle parts of mandibles with two teeth. Although this specimen is fragmentary, it is evident that odontocetes lived in this region during the time of deposition of the Korematsu Formation. However, questions remain as to why there are so few odontocete specimens relative to mysticetes.



Keywords: Burdigalian, Cetacea, Langhian, mandible, Odontoceti

Introduction

The suborders Odontoceti (toothed whales) and Mysticeti (baleen whales) comprise the Neoceti or crown Cetacea (Fordyce and de Muizon, 2001). Early odontocetes from the Oligocene have heterodont teeth and poorly telescoped skulls (Fordyce, 2002; Sanders and Geisler, 2015). Like the Platanistidae and Ziphiidae, early members of modern groups appeared in the Early Miocene (Marx *et al.*, 2016). Thus, the Early Miocene was a time of transition from archaic odontocetes to modern ones (Bianucci and Landini, 2007).

* Corresponding author: Yoshihiro TANAKA (yoshi.tanaka.research@gmail.com)

This article is licensed under a Creative Commons [Attribution 4.0 International] license.
© 2026 The Authors.

Many Early Miocene odontocetes have been reported since the 2010s from Italy (Bisconti *et al.*, 2020), Malta (Bianucci *et al.*, 2011), Argentina (Viglino *et al.*, 2018, 2019, 2020, 2022; Gaetán *et al.*, 2019, 2025), Peru (Lambert *et al.*, 2015, 2017; Bianucci *et al.*, 2018, 2020), Washington, Oregon, Maryland and Virginia in the USA (Boersma *et al.*, 2017; Lambert *et al.*, 2018; Nelson and Uhen, 2018; Peredo *et al.*, 2018; Godfrey and Lambert, 2023), New Zealand (Aguirre-Fernández and Fordyce, 2014; Tanaka and Fordyce, 2015, 2016; Tanaka *et al.*, 2023) and Japan (see next).

In Japan, there are horizons that preserve Early to early Middle Miocene odontocete fossils, such as the Ichishi Group in Mie, the Mizunami and Iwamura groups in Gifu, the Morozaki Group in Aichi, and some formations in Akita, Iwate and Hokkaido (Table 1) (Oishi and Hasegawa, 1995; Ichishima, 2005). Several nominal species have been established based on specimens derived

Table 1. Reported Early to early Middle Miocene odontocetes from Japan with morphological description. Abbreviations: Fr., formation; Gr., Group; cf., confer; sp., species. See also institutional abbreviation section.

Horizon	Specimen	Identification	Parts	Age	Localities	Reference
Korematsu Fm., Bihoku Gr.	HMN-F30103	Odontoceti indet.	mandibles	16.1 to 15.6 Ma, late Early to early Middle Miocene	Miyoshi City, Hiroshima	This study
Korematsu Fm., Bihoku Gr.	HMN-F30102	cf. Odontoceti	right humerus	16.1 to 15.6 Ma, late Erly to early Middle Miocene	Shobara City, Hiroshima	Tanaka *et al.*, 2020
Hiramatsu Fm., Ichishi Gr.	GMNH-PV-2570, Holotype	*Ninjadelphis ujiharai*	partial skeleton including skull, periotics, tympanic bullae, mandibles and forelimb elements	17 Ma, late Early Miocene	Iga City, Mie	Kimura and Barnes, 2016
Haze Fm., Ichishi Gr.	MPM-Fo1058, Holotype	*Miodelphinus miensis*	Skull, right and left periotics and tym- panic bullae, right incus and malleus, four isolated teeth, three possible hyoid bones and two ribs	18.7 to 18.5 Ma, Early Miocene	Tsu City, Mie	Tanaka and Nakagawa, 2024
Oi Fm., Ichishi Gr.	MFM 53701	Odontoceti	forelimb	Early Miocene	Tsu City, Mie	Kimura and Kaede, 2016
Oi Fm., Ichishi Gr.	private specimens	cf. *Stenella kabatensis* (now *Eodelphinus kabatensis*)	three teeth	Early Miocene	Tsu City, Mie	Matsuhashi and Ooyagi, 2013
Oi Fm., Ichishi Gr.	private specimens	Delphinidae indet.	periotic and two teeth	Early Miocene	Tsu City, Mie	Matsuhashi and Ooyagi, 2013
Oi Fm., Ichishi Gr.	private specimen	Delphinoidea indet.	tooth	Early Miocene	Tsu City, Mie	Matsuhashi and Ooyagi, 2013
Oi Fm., Ichishi Gr.	private specimens	cf. *Scaldicetus* sp.	two teeth	Early Miocene	Tsu City, Mie	Matsuhashi and Ooyagi, 2013
Oi Fm., Ichishi Gr.	private specimens	Odontoceti indet.	two teeth	Early Miocene	Tsu City, Mie	Matsuhashi and Ooyagi, 2013
Oi Fm., Ichishi Gr.	WMNH-Ge-1121340002	Odontoceti indet.	mandibles	17.2 to 16.3 Ma, Early Miocene	Tsu City, Mie	Tanaka *et al.*, 2021
Yamanouchi Fm., Mizunami Gr.	MFM	*Aulophyseter* sp.	skull, mandible, teeth and atlas	Early Miocene	Mizunami City, Gifu	Okazaki, 1992
Akeyo Fm., Mizunami Gr.	MFM	Platanistoidea?	right scapula, humerus, ulna, radius and carpals	Early Miocene	Mizunami City, Gifu	Kamei and Okazaki, 1974; Ichishima, 2005
Akeyo Fm., Mizunami Gr.	MFM 18002, Holotype	*"Eurhinodelphis" minoensis* re-identified as an odontoceti	mandibles, vertebrae, ribs, teeth	Early Miocene	Mizunami City, Gifu	Okazaki, 1976; Ichishima, 2005
Akeyo Fm., Mizunami Gr.	MFM 18003	*"Eurhinodelphis" minoensis* re-identified as an odontoceti	mandibles and teeth	Early Miocene	Mizunami City, Gifu	Okazaki, 1976; Ichishima, 2005
Akeyo Fm., Mizunami Gr.	MFM	*Eurhinodelphis* sp. A. re-identified as a kentriodontid	skull and ear bones	Early Miocene	Mizunami City, Gifu	Okazaki, 1976; Ichishima, 2005
Toyama Fm., Iwamura Gr.	MFM 18190	Squalodelphinidae indet.	left periotic, right tympanic bulla and right malleus	17 to 16 Ma, Early Miocene	Mizunami City, Gifu	Kimura, 2019
Morozaki Gr.	TMNH 10785, Holotype	*Miophyseter chitaensis*	skull, periotic, tympanic bulla and skeleton	Early Miocene	Minamichita, Aichi	Chita−kujira Excavation Research Group, 1993; Kimura and Hasegawa, 2022, 2023
Bessho Fm.	SFM-00001, Holotype	*Brygmophyseter shigensis*	skeleton	early Middle Miocene	Matsumoto, Nagano	Hirota and Barnes, 1995; Kimura *et al.*, 2006
Bessho Fm.	MCM-56221	Ziphiidae indet.	skull	early Middle Miocene	Matsumoto, Nagano	Hasegawa and Kimura, 2003
Bessho Fm.	KIM-1, Holotype	*Sinanodelphis izumidaensis*	skull, vertebrae and forelimb	early Middle Miocene	Aoki, Nagano	Makiyama, 1936; Kohno *et al.*, 2007
Bessho Fm.	MCM-56211	Delphinoidea indet.	skull	early Middle Miocene	Matsumoto, Nagano	Kohno *et al.*, 2007
Kadonosawa Fm.	IGPS 59740	*Scaldicetus* indet.	tooth	late Early to early Middle Miocene	Ninohe City, Iwate	Matsumoto, 1926; Kohno and Ray, 2008
Sugota Fm.	UTHFM 00034, Holotype	*Platysvercus ugonis*	skull	16.7 to 16.29 Ma, Early Miocene	Ugo Town, Akita	Guo and Kohno, 2023
Kadonosawa Fm.	NMHF 999, Holotype	*Kentriodon sugawarai*	skull, one tooth, the right tympanoperiotic, malleus, mandibles and atlas	late Early to early Middle Miocene	Ninohe City, Iwate	Guo and Kohno, 2021
Takinoue Fm.	HMG 387, Holotype	*Kentriodon hobetsu*	skull	early Middle Miocene	Mukawa, Hokkaido	Ichishima, 1995

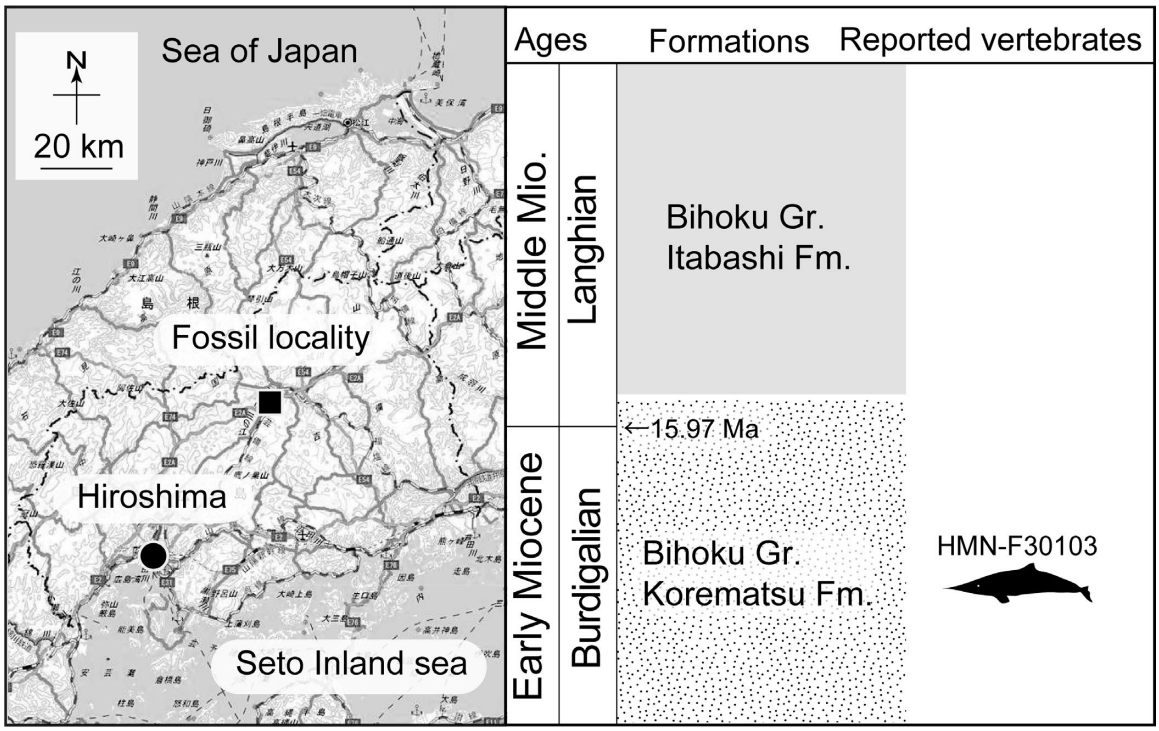


Figure 1. Map showing the locality of HMN-F30103, Odontoceti indet. The base map was published by the Geospatial Information Authority of Japan. Abbreviations: Fr., formation; Gr., Group; Mio., Miocene.

from these areas (Kimura and Barnes, 2016; Guo and Kohno, 2021, 2023; Kimura and Hasegawa, 2022; Tanaka and Nakagawa, 2024).

Abundant fossils of baleen whales are known from the Bihoku Group in Hiroshima (Kimura *et al.*, 2007, 2010, 2011; Ohzawa *et al.*, 2007; Otsuka and Ota, 2008; Tsai, 2017). In contrast, only one possible toothed whale fossil identified as cf. Odontoceti has been reported from this unit (Tanaka *et al.*, 2020). The specimen is a 9 cm long right humerus, which shows an unusual shape, including a flat shaft and a proximally well projected common tubercle. It is similar to the humerus of odontocetes in that it has a deep fossa for the infraspinatus. However, the attribution to Odontoceti remains tentative. Here, we report the first unambiguous record of Odontoceti from the Bihoku Group (latest Early to earliest Middle Miocene) in Miyoshi, Hiroshima, Japan.

Institutional abbreviations.—GMNH, Gunma Museum of Natural History, Gunma, Japan; HMG, Hobetsu Museum, Mukawa, Hokkaido, Japan; HMN, Hiwa Museum for Natural History, Hiroshima, Japan; HUM, Hiroshima University Museum, Hiroshima, Japan; IGPS, Institute of Geology and Paleontology, Tohoku University, Sendai, Miyagi, Japan; KIM, Kohsenji Izumida Museum, Ueda, Nagano, Japan; MCM, Matsumoto City Museum, Matsumoto, Nagano, Japan; MFM, Mizunami Fossil Museum, Mizunami, Gifu, Japan; MPM, Mie Prefectural Museum, Tsu, Mie, Japan; NMHF, Ninohe Museum of History and Folklore, Ninohe, Iwate, Japan; MSFM, Matsumoto City Shiga Fossil Museum, Matsumoto, Nagano, Japan; SFM, Shobara Kaseki Shudankai Fossil Museum, Shobara, Hiroshima, Japan; TMNH, Toyohashi Museum of Natural History, Toyohashi, Aichi, Japan; UTHFM, Ugo Town History and Folklore Museum, Ogachi, Akita, Japan; WMNH, Wakayama Prefectural Museum of Natural History, Kainan, Wakayama, Japan.

Material and methods

The new specimen (HMN-F30103) was discovered in August 1979 by Noriko Ochi from the Bihoku Group in Nishisakeyamachi, Miyoshi, Hiroshima, Japan. In this area, the Bihoku Group is divided into the lower Kurematsu Formation, which comprises sandstones, and the upper Itabashi Formation, which comprises shales (Seto and Yamauchi, 2009). Based on the matrix of the specimen, HMN-F30103 was derived from the Kurematsu Formation. The paleoenvironment of the Kurematsu Formation was a bay characterized by a mangrove community (Seto and Yamauchi, 2009). The age of the Kurematsu Formation in this area was estimated as 16.1 to 15.6 Ma (latest Burdigalian to earliest Langhian;

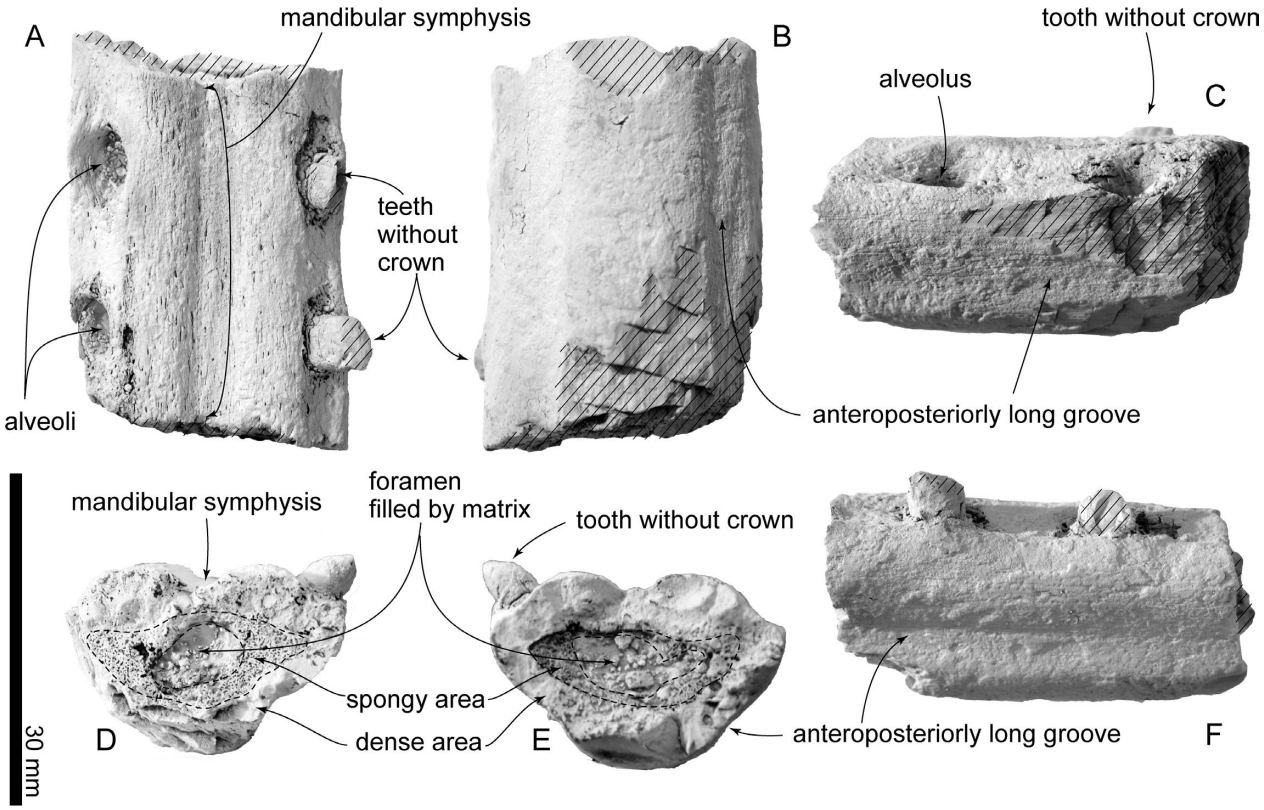


Figure 2. Lower jaw of HMN-F30103, Odontoceti indet. **A,** dorsal view; **B,** ventral view; **C,** left lateral view; **D,** posterior view; **E,** anterior view; **F,** right lateral view.

latest Early to earliest Middle Miocene) based on microfossils (Yamamoto, 1999). Preparation of the fossil was completed by Toshiyuki Kimura and one of the authors (YT) using pneumatic scribes and immersion of a block in dilute 4% acetic acid.

Systematic paleontology

Order Cetacea Brisson, 1762
Unranked clade Neoceti Fordyce & de Muizon, 2001
Suborder Odontoceti Flower, 1867
Odontoceti indet.

Figure 2

Referred specimen.—HMN-F30103, the middle part of a fused and narrow mandibular symphysis with two single-rooted teeth in life position.

Locality.—Nishisakeyamachi, Miyoshi, Hiroshima, Japan: Latitude 34°47′08″N, longitude 132°50′47″E (Figure 1).

Horizon and age.—Korematsu Formation, Bihoku Group. Latest Burdigalian to earliest Langhian; latest Early to earliest Middle Miocene (16.1 to 15.6 Ma: Yamamoto, 1999).

General description

Terminology for mandibular osteology follows Mead and Fordyce (2009).

Ontogeny.—HMN-F30103 shows individualized and ossified alveoli. This indicates that the animal was probably not a juvenile. For example, juveniles of *Pontoporia blainvillei* have an open alveolar groove instead of individualized and ossified alveoli (Gutstein *et al.*, 2009).

Mandible.—HMN-F30103 is a pair of fused mandibles with two teeth missing their crowns. No indications could be found for a mesorostral groove or for sutures of the premaxilla, maxilla, and vomer, so this fragment can be confidently identified as a part of a mandible. The mandibular fragment is 37.7 mm long, 25.7 mm wide and 17.1 mm in height excluding the teeth. The right and left mandibles are completely fused. The surface of the mandibles is smooth. The mandibles exhibit dorsally swollen lateral parts and the mandibular symphysis as a weak groove on the dorsal surface (Figure 2A).

The minimum distances between right and left alveoli is 14.9 and 17.4 mm for the two preserved pairs of alveoli. This difference may be explained by the anterior nar-

rowing of the mandible, as seen in many odontocetes, the anterior side being this the narrowest. Thus, the two preserved teeth are probably from the right side (Figure 2).

Two open alveoli are preserved on the presumed left side, which are circular openings (the anterior alveolus is 6.6 mm long and 6.1 mm wide, and the posterior alveolus is 6.3 mm long and 5.8 mm wide). Around the alveoli, the lateral borders of the mandibles are nearly rectilinear in dorsal and lateral views (Figure 2A, C and F). The alveoli are shallow (about 5 mm deep) with smooth walls.

On the ventrolateral surfaces of the right and left mandibles (Figure 2B, C and F), there are a couple of long, shallow grooves running anteroposteriorly. Between the grooves, there is a ventrally swollen ventromedial part. In anteroposterior view (Figure 2D and E), the mandible is heart-shaped. The cross-sections show a foramen filled by the matrix at the center of the bone, which is surrounded by dense bone.

Teeth.—Two single-rooted teeth are preserved in life position. The crowns are broken away. In cross section, the roots are transversely flattened and elliptical in cross section (anterior tooth: 5.4 mm long and 4.4 mm wide; posterior tooth: 4.8 mm long and 3.9 mm wide).

Discussion

HMN-F30103 is an odontocete because it has single rooted teeth, which is not a feature in true or toothless baleen whales (Chaeomysticeti). Early mysticetes had teeth and originated before the Early Miocene (Marx *et al.*, 2024). Some have both double- and single-rooted teeth (e.g. *Mammalodon*: Fitzgerald, 2010; *Coronodon*: Boessenecker *et al.*, 2023), whereas others have only single rooted teeth (e.g. *Aetiocetus*: Emlong, 1966). However, toothed baleen whales differ from HMN-F30103 in having anteroposteriorly long posterior teeth with wide robust roots and in lacking mandibles with parallel sided lateral surfaces and long mandibular symphysis. Crocodiles also have a similar mandibular morphology but have cranial ornamentation (Clarac *et al.*, 2015). Thus, HMN-F30103 is different from crocodiles with smooth surface of the bone and walls of the alveoli.

More precise identification of HMN-F30103 is challenging, as several different odontocete lineages share narrow mandibles with an anteroposteriorly long mandibular symphysis (e.g. Allodelphinidae, Squalodelphinidae, Platanistidae, Eoplatanistidae and Kentriodontidae). See Table 2 for a detailed comparison of these families. Although HMN-F30103 preserves only partial mandibles, it possesses shallow anteroposteriorly long grooves on the ventrolateral side, circular alveoli, cross sections being transversely wider than high, and more or less the same length of the alveoli and interalveolar spaces. Among the odontocetes used for comparison, only WMNH-Ge-11121340002, Odontoceti indet. shows the same combination of these four features. However, these four features are not diagnostic, even at the family level (Table 2). For example, among squalodelphinids, *Squalodelphis fabianii* has shallow longitudinal grooves on the ventrolateral surface of the mandible, whereas *Notocetus vanbenedeni* lacks such grooves.

There are several nominal Early to early Middle Miocene odontocete species from Japan (*Ninjadelphis ujiharai*, *Miophyseter chitaensis*, *Brygmophyseter shigensis*, *Sinanodelphis izumidaensis*, *Platysvercus ugonis*, *Kentriodon sugawarai*, *Kentriodon hobetsu*, *Miodelphinus miensis* and *"Eurhinodelphis" minoensis*. See citations in Table 1). Lambert (2004) identified the holotype of *"E." minoensis* as Odontoceti incertae sedis because the specimen does not preserve diagnostic characters at the generic level. Among the odontocetes from the Early to early Middle Miocene of Japan, only *N. ujiharai*, *B. shigensis*, *S. izumidaensis*, *K. sugawarai*, and *"E." minoensis* have mandibular material preserved. *K. sugawarai* preserves a posterior part of the mandible, and *S. izumidaensis* preserves an anterior part of the mandible visible only in lateral view, because the specimen is still embedded in matrix. *Ninjadelphis ujiharai* differs from HMN-F30103 in having deeper anteroposteriorly elongated grooves on the ventrolateral surface of the mandible and a deep groove on the median line of the dorsal surface of the mandibular symphysis. *Brygmophyseter shigensis* differs from HMN-F30103 in having large teeth with interalveolar spaces shorter than the anteroposterior length of teeth and a deep groove on the median line of the dorsal surface of the mandibular symphysis. *"Eurhinodelphis" minoensis* differs from HMN-F30103 in having deeper anteroposteriorly elongated grooves on the ventrolateral surface of the mandible, but it is similar in having a shallow groove on the median line of the dorsal surface of the mandibular symphysis. WMNH-Ge-11121340002, a Y-shaped portion of the posterior end of a long mandibular symphysis preserving several alveoli from the Oi Formation (Ichishi Group), was referred to Odontoceti indet. (Tanaka *et al*., 2021). WMNH-Ge-11121340002 differs from HMN-F30103 in having a deeper groove on the median line of the dorsal surface of the mandibular symphysis, but it is similar in having shallow anteroposteriorly elongated grooves on the ventrolateral surface of the mandible.

The taxonomy of several reported specimens is uncertain (Table 1). In Japan, the Early to early Middle Miocene odontocetes are classified into the Physeteridae, Squalodelphinidae, Allodelphinidae, Ziphiidae and Kentriodontidae. The two families Squalodelphinidae and Allodelphinidae have only recently been recognized from

Table 2. Comparison of long and narrow mandibles of some Early to early Middle Miocene odontocetes, derived from Table 2 of Tanaka *et al.* (2021).

Family	Scientific name or specimen number	Age	long groove on ventrolateral side	alveolar shape	mandibular symphysis width and height, at preserved most posterior part or anterior to diverging point of the mandibles	length of alveoli vs interalveolar spaces, at preserved most posterior part or anterior to diverging point of the mandibles	Used references for comparison
Odontoceti indet.	HMN-F30103, partly preserved mandible	late Early to early Middle Miocene	shallow	circular	wider	more or less the same	This study
Odontoceti indet.	WMNH-Ge-1121340002, partly preserved mandible	late Early Miocene	shallow	circular	wider	more or less the same	Tanaka *et al.*, 2021
Odontoceti indet.	*"Eurhinodelphis" minoensis*, holotype	Early Miocene	shallow	circular	wider	more or less the same at the level of the posterior end of the mandibular symphysis, and alveoli are longer at the anterior part of the mandibles	Okazaki, 1976
Allodelphinidae	*Ninjadelphis ujiharai*, holotype GMNH-PV-2570	late Early Miocene	deep	circular	more or less the same	shorter interalveolar space	Kimura and Barnes, 2016
Squalodelphinidae	*Squalodelphis fabianii*, holotype MGP 26134	Early Miocene	shallow	circular	wider	longer interalveolar space	Pilleri, 1985
Squalodelphinidae	*Notocetus vanbenedeni*, MLP 5-10	Early Miocene	absent	circular	wider	more or less the same	Lydekker, 1894; Viglino *et al.*, 2022
Platanistidae	*Araeodelphis natator*, holotype USNM 10478	Early to early Middle Miocene	shallow	circular	wider	shorter interalveolar space	Kellogg, 1957
Platanistidae	*Pomatodelphis inaequalis*, USNM 6683, partly preserved mandible	Middle to Late Miocene	shallow	anteroposteriorly longer	wider	shorter interalveolar space	Kellogg, 1959
Allodelphinidae	*Zarhinocetus errabundus*, LACM 149588	Middle Miocene	deep	anteroposteriorly longer	wider	shorter interalveolar space	Kellogg, 1931, Kimura and Barnes, 2016
Eoplatanistidae	*Eoplatanista italica* holotype MGP 26150, 26151	Early Miocene	shallow	anteroposteriorly longer	?	shorter interalveolar space	Pilleri, 1985
Eurhinodelphinidae	*Xiphiacetus bossi*, holotype USNM 8842	Early to Middle Miocene	deep	circular	wider	shorter interalveolar space	Kellogg, 1925
Eurhinodelphinidae	*Schizodelphis sulcatus*, MGP 26154	Early to Middle Miocene	shallow	anteroposteriorly longer	?	longer interalveolar space	Pilleri, 1985
Kentriodontidae	*Belonodelphis peruanus*, holotype MNHN PPI 231	Late Miocene	shallow	anteroposteriorly longer	wider	shorter interalveolar space	Muizon, 1988

Table 3. Reported mysticetes from the Bihoku Group in Miyoshi and Shobara. Some fragmentary materials reported by Otsuka and Ota (2008) are omitted. Abbreviations: Fr., formation; Gr., Group; cf., confer; sp., species. See also institutional abbreviation section.

Horizon	Specimen	Identification	Age	Locality	Reference
Korematsu Fm.	HMN-F00003	*Pelocetus* sp.	Early to Middle Miocene	Shobara City	Kimura *et al.*, 2007
Itabashi Fm.	HMN-F00004	*Parietobalaena* cf. *yamaokai*	Middle Miocene	Shobara City	Kimura *et al.*, 2010: Ohzawa *et al.*, 2007
Korematsu Fm.	HMN-F00005–9 (IDs for the same individual)	*Diorocetus shobarensis,* holotype	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00010, 12–19 (IDs for the same individual)	*Diorocetus shobarensis,* holotype	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00021	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00022–24 (IDs for the same individual)	*Parietobalaena yamaokai*, holotype	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00025	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00026	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00027	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00035, 36, 38, 40, 41	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00042–44, 54	*Parietobalaena yamaokai*, paratype	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008; Ohzawa *et al.*, 2013
Korematsu Fm.	HMN-F00045–47, 49, 51, 53	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00060	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00061	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00062	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00063	*Diorocetus shobarensis*, paratype	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00064–80 (seems a series belongs to an individual)	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00081	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00082	*Pelocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00083	*Pelocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00084	*Hibacetus hirosei*, holotype	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00085	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00086, 87	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Itabashi Fm.	HMN-F00088–92, 94–97	cetacea	Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00098	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00106–115	*Pelocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00117	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00118	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00119	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00120	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00121	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00122	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00123	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00124	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00125	*Aglaocetus* sp.	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008
Korematsu Fm.	HMN-F00127, 128	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Otsuka and Ota, 2008; Tsai, 2017
Korematsu Fm.	HMN-F00640	*Parietobalaena yamaokai*	Early to Middle Miocene	Shobara City	Kimura *et al.*, 2011
Itabashi Fm.	HMN-F11569	cf.*Diorocetus shobarensis*	Middle Miocene	Shobara City	Kiyoshi *et al.*, 2020
Itabashi Fm.	HMN-F20256–72 (IDs for the same individual)	Cetacea indet.	Middle Miocene	Shobara City	Furukawa *et al.*, 2004
unknown	SFM-00100	Cetotheriidae indet.	Middle Miocene	Shobara City	Ohzawa and Yamaoka, 2003
Itabashi Fm.	SFM-00106	cf. Cetotheriidae	Middle Miocene	Shobara City	Ohzawa and Yamaoka, 2003
Itabashi Fm.	SFM-00107	cf. Cetotheriidae	Middle Miocene	Shobara City	Ohzawa *et al.*, 2001
Korematsu Fm.	SFM-00111	Cetacea indet.	Early to Middle Miocene	Shobara City	Yamaoka *et al.*,1995
Korematsu Fm.	HUM-F-00253	Cetacea indet.	Early to Middle Miocene	Shobara City	Imamura, 1953
Korematsu Fm.	KFM-0003–23 (IDs for the same individual)	Mysticeti indet.	latest Early Miocene	Miyoshi City	Kimita Village and Kimita Village Education Board, 2003; Otsuka, 2008

Japanese strata in the past decade (Kimura and Barnes, 2016; Kimura *et al.*, 2019). Those recent records suggest that various species of squalodelphinids and allodelphinids diversified and existed in the northeastern Pacific by the Early Miocene (Kimura and Barnes, 2016; Tanaka and Nakagawa, 2024).

As mentioned above, abundant baleen whale fossils have been reported from the Bihoku Group. Over 10 baleen whale specimens have been reported from the Bihoku Group in the cities of Miyoshi and Shobara, including fossils referred to *Parietobalaena yamaokai*, *Pelocetus* sp., *Hibacetus hirosei*, *Aglaocetus* sp., and *Diorocetus shobarensis* (Table 3) (Imamura, 1953; Yamaoka, 1995; Ohzawa *et al.*, 2001, 2007, 2013; Kimita Village and Kimita Village Education Board, 2003; Ohzawa and Yamaoka, 2003; Furukawa *et al.*, 2004; Kimura *et al.*, 2007, 2010, 2011; Otsuka and Ota, 2008; Otsuka, 2008; Tsai, 2017; Kiyoshi *et al.*, 2020). HMN-F30103 is the first unambiguous odontocete from the Bihoku Group. In short, the cetacean fossil record of the Bihoku Group comprises many mysticetes and only a few odontocetes. However, this trend is not widely seen in the world. The marine vertebrate fossil assemblage of the Lower Miocene Chilcatay Formation in Peru is dominated by odontocetes (Di Celma *et al.*, 2018). Marx *et al.* (2019) reported several fossil localities of Oligocene–Miocene boundary preserving odontocetes but lacking mysticetes altogether.

Here we consider sampling, research, and taphonomic biases to try to explain why only one unambiguous odontocete fossil is known from the Bihoku Group when many mysticete fossils have been reported. In northern Japan, 33 odontocete fossils and 23 mysticete fossils have been reported from Hokkaido, and nine odontocete fossils and 72 mysticete fossils have been reported from Tohoku (Ichishima, 2024). Ichishima (2024) concluded that the number of reports from each of those regions is affected by research bias, noting the current data are insufficient to explain whether paleoenvironmental factors also contributed to the apparent differences. Three of the authors (TK, TY and HO) contributed to cataloguing the fossil collections from Shobara and Miyoshi at the Hiwa Museum for Natural History. Additionally, the authors have collected and prepared the majority of the cetacean fossils from these regions by ourselves, and with the exception of one isolated single rooted conical tooth, we have never seen another odontocete fossil. Having observed all known cetacean fossils from the Bihoku Group, we therefore conclude that research bias is not the cause of the low number of odontocetes relative to mysticetes. A sampling bias owing to body size is unlikely, because specimens as small as shark teeth only a few centimeters in size have been collected from the Korematsu Formation in Miyoshi and Shobara (Nakano, 1999). Although the reason for the low number of odontocetes in the Bihoku Group remains unclear, we at least reject research and sampling biases as potential factors.

Conclusion

Although fragmentary, the partial mandibular fossil HMN-F30103 is the first unambiguous record of Odontoceti from the Bihoku Group in Miyoshi, Hiroshima, Japan. This new specimen provides evidence that odontocetes lived in the area during the latest Early to earliest Middle Miocene (approximately 16.1 to 15.6 Ma). However, questions remain as to why so few odontocete fossils have been recovered from the Bihoku Group relative to mysticetes.

Acknowledgements

We thank Noriko Ochi for donating the studied material. Thanks also go to Toshiyuki Kimura (Gunma Museum of Natural History) for the initial preparation of the studied material and Yusuke Ando (Mizunami Fossil Museum) for providing comparative specimen photos. We thank the two reviewers Olivier Lambert (Institut royal des Sciences naturelles de Belgique) and Mariana Viglino (Instituto Patagónico de Geología y Paleontología (IPGP), CCT CONICET-CENPAT), and associate editor Hiroto Ichishima (Fukui Prefectural Dinosaur Museum) for their constructive comments that helped improve the manuscript.

References

Aguirre-Fernández, G. and Fordyce, R. E., 2014: *Papahu taitapu*, gen. et sp. nov., an early Miocene stem odontocete (Cetacea) from New Zealand. *Journal of Vertebrate Paleontology*, vol. 34, p. 195–210.

Bianucci, G., Bosio, G., Malinverno, E., de Muizon, C., Villa, I. M., Urbina, M. *et al.,* 2018: A new large squalodelphinid (Cetacea, Odontoceti) from Peru sheds light on the Early Miocene platanistoid disparity and ecology. *Royal Society Open Science*, vol. 5, 172302.

Bianucci, G., de Muizon, C., Urbina, M. and Lambert, O., 2020: Extensive diversity and disparity of the Early Miocene platanistoids (Cetacea, Odontoceti) in the Southern Pacific (Chilcatay Formation, Peru). *Life*, vol. 10, p. 1–62.

Bianucci, G., Gatt, M., Catanzariti, R., Sorbi, S., Bonavia, C. G., Curmi, R. *et al.*, 2011: Systematics, biostratigraphy and evolutionary pattern of the Oligo-Miocene marine mammals from the Maltese Islands. *Geobios*, vol. 44, p. 549–585.

Bianucci, G. and Landini, W., 2007: Fossil history. *In*, Miller, D. L. *ed*., *Reproductive Biology and Phylogeny of Cetacea: Whales, Dolphins and Porpoises*, p. 35–93. Science Publishers, Enfield.

Bisconti, M., Damarco, P., Tartarelli, G., Pavia, M. and Carnevale, G., 2020: A natural endocast of an early Miocene odontocete and its implications in cetacean brain evolution. *Journal of Comparative Neurology*, vol. 529, p. 1198–1227.

Boersma, A. T., McCurry, M. R. and Pyenson, N. D., 2017: A new fossil dolphin *Dilophodelphis fordycei* provides insight into the evolution of supraorbital crests in Platanistoidea (Mammalia, Cetacea). *Royal Society Open Science*, vol. 4, 170022.

Brisson, A. D., 1762: *Regnum Animale in Classes IX Distributum Sive Synopsis Methodica*, 296 p. Theodorum Haak, Leiden.

Chita-kujira Excavation Research Group, 1993: Odontocete fossils from the Miocene Morozaki Group, Chita Peninsula, Aichi Prefecture, Central Japan. *Earth Science*, vol. 47, p. 153–157. (*in Japanese*)

Clarac, F., Souter, T., Cornette, R., Cubo, J. and de Buffrenil, V., 2015: A quantitative assessment of bone area increase due to ornamentation in the Crocodylia. *Journal of Morphology*, vol. 276, p. 1183–1192.

de Muizon, C., 1988: Les vertébrés fossiles de la formation Pisco (Pérou) III: Les odontocètes (Cetacea, Mammalia) du Miocène. *Rocherches sur les Civilisations*, vol. 78, p. 1–128.

Di Celma, C., Malinverno, E., Collareta, A., Bosio, G., Gariboldi, K., Lambert, O. *et al.*, 2018: Facies analysis, stratigraphy and marine vertebrate assemblage of the lower Miocene Chilcatay Formation at Ullujaya (Pisco basin, Peru). *Journal of Maps*, vol. 14, p. 257–268.

Emlong, D., 1966: A new archaic cetacean from the Oligocene of northwest Oregon. *Bulletin of the Museum of Natural History*, *University of Oregon*, vol. 3, p. 1–51.

Fitzgerald, E. M. G., 2010: The morphology and systematics of *Mammalodon colliveri* (Cetacea: Mysticeti), a toothed mysticete from the Oligocene of Australia. *Zoological Journal of the Linnean Society*, vol. 158, p. 367–476.

Flower, W. H., 1867: Description of the skeleton of *Inia geoffrensis* and the skull of *Pontoporia blainvillii*, with remarks on the systematic position of these animals in the Order Cetacea. *Transactions of the Zoological Society of London*, vol. 6, p. 87–116.

Fordyce, R. E., 2002: *Simocetus rayi* (Odontoceti: Simocetidae, new family): A bizarre new archaic Oligocene dolphin from the eastern North Pacific. *Smithsonian Contributions to Paleobiology*, vol. 93, p. 185–222.

Fordyce, R. E. and de Muizon, C., 2001: Evolutionary history of the cetaceans: a review. *In*, Mazin, J.-M. and de Buffrenil, V. *eds.*, *Secondary Adaptation of Tetrapods to Life in Water*, p. 169–234. Verlag Dr. Friedrich Pfeil, München.

Furukawa, Y., Yamaoka, T. and Ohzawa, H., 2004: Whale fossils from the Miocene Bihoku Group in the Shobara City, Hiroshima Prefecture, West Japan. *Journal of the Hiba Society of Natural History*, vol. 213, p. 17–23. (*in Japanese with English abstract*)

Gaetán, C. M., Buono, M. R. and Gaetano, L. C., 2019: *Prosqualodon australis* (Cetacea: Odontoceti) from the Early Miocene of Patagonia, Argentina: Redescription and phylogenetic analysis. *Ameghiniana*, vol. 56, p. 1–27.

Gaetán, C. M., Buono, M. R., Tanaka, Y., Farroni, N. D. and Milano, V. N., 2025: Echoes from the Miocene: tracing the anatomy and phylogeny of *Prosqualodon australis* (Cetacea: Odontoceti). *Journal of Systematic Palaeontology*, vol. 23, 2455753.

Godfrey, S. J. and Lambert, O., 2023: Miocene toothed whales (Odontoceti) from Calvert Cliffs, Atlantic Coastal Plain, USA. *Smithsonian Contributions to Paleobiology*, vol. 107, p. 49–186.

Guo, Z. and Kohno, N., 2021: A new kentriodontid (Cetacea: Odontoceti) from the early to middle Miocene of the western North Pacific and a revision of kentriodontid phylogeny. *PeerJ*, vol. 9, e10945.

Guo, Z. and Kohno, N., 2023: An Early Miocene kentriodontoid (Cetacea: Odontoceti) from the western North Pacific, and its implications for their phylogeny and paleobiogeography. *Plos One*, vol. 18, e0280218.

Gutstein, C. S., Cozzuol, M. A., Vargas, A. O., Suárez, M. E., Schultz, C. L. and Rubilar-Rogers, D., 2009: Patterns of skull variation of *Brachydelphis* (Cetacea, Odontoceti) from the Neogene of the Southeastern Pacific. *Journal of Mammalogy*, vol. 90, p. 504–519.

Hirota, K. and Barnes, L. G., 1995: A new species of Middle Miocene sperm whale of the genus *Scaldicetus* (Cetacea; Physeteridae) from Shiga-mura, Japan. *Island Arc*, vol. 3, p. 453–472.

Ichishima, H., 1995: A new fossil kentriodontid dolphin (Cetacea; Kentriodontidae) from the Middle Miocene Takinoue Formation, Hokkaido, Japan. *Island Arc*, vol. 3, p. 473–485.

Ichishima, H., 2005: A re-evaluation of some Japanese cetacean fossils. *Memoir of the Fukui Prefectural Dinosaur Museum*, vol. 4, p. 1–20. (*in Japanese with English abstract*)

Ichishima, H., 2024: Fossil cetaceans of Hokkaido and Tohoku districts. *Journal of Fossil Research*, vol. 57, p. 3–14. (*in Japanese with English abstract*)

Imamura, S., 1953: Miyoshi, Mirasaka and Shobara districts. *In*, Geological laboratory of Hiroshima University *ed*., Geologial travel guide, p. 19–41. Geological laboratory of Hiroshima University, HIroshima. (*in Japanese*)

Kamei, T. and Okazaki, Y., 1974: Mammalian fossils from the Mizunami Group, Central Japan. *Bulletin of Mizunami Fossil Museum*, vol. 1, p. 263–291. (*in Japanese*)

Kellogg, R., 1925: On the occurrence of remains of fossil porpoises of the genus *Eurhinodelphis* in North America. *Proceedings of the United States National Museum*, vol. 66, p. 1–40.

Kellogg, R., 1931: Pelagic mammals from the Temblor Formation of the Kern River region, California. *Proceedings of the California Academy of Sciences,* vol. 19, p. 217–397.

Kellogg, R., 1957: Two additional Miocene porpoises from the Calvert Cliffs, Maryland. *Proceedings of the United States National* Museum, *vol*. 107, p. 279–337.

Kellogg, R., 1959: Description of the skull of *Pomatodelphis inaequalis* Allen. *Bulletin of the Museum of Comparative Zoology*, vol. 121, p. 1–26.

Kimita Village and Kimita Village Education Board, 2003: *Report of Fossil Whale from Kimita Village, Hiroshima Prefecture*, 96 p. Kimita Village and Kimita Village Education Board, Hiroshima.

Kimura, T., 2019: First squalodelphinid from the early Miocene of the Pacific realm in the Northern Hemisphere. *Journal of Vertebrate Paleontology*, vol. 38, p. 1–6.

Kimura, T. and Barnes, L. G., 2016: New Miocene fossil Allodelphinidae (Cetacea, Odontoceti, Platanistoidea) from the North Pacific Ocean. *Bulletin of Gunma Museum of Natural History*, vol. 20, p. 1–58.

Kimura, T. and Hasegawa, Y., 2022: A new physeteroid from the Lower Miocene of Japan. *Paleontological Research,* vol. 26, p. 87–101.

Kimura, T. and Hasegawa, Y., 2023: Additional rostrum fragments of the holotype of *Miophyseter chitaensis*. *Bulletin of Gunma Museum of Natural History*, vol. 27, p. 107–112. (*in Japanese with English abstract*)

Kimura, T., Hasegawa, Y. and Barnes, L. G., 2006: Fossil sperm whales (Cetacea, Physeteridae) from Gunma and Ibaraki prefecture, Japan; with observation on the Miocene fossil sperm whale Scaldicetus shigensis Hirota and Barns,1995. *Bulletin of the Gunma Museum of Natural History*, vol. 10, p. 1–23.

Kimura, T., Hasegawa,Y., Ohzawa, H., Ueda, T. and Yamaoka, T., 2010: A fossil mysticete from the middle Miocene Bihoku Group, Hiroshima, Japan. *Bulletin of Gunma Museum of Natural History*, vol. 14, p. 29–36. (*in Japanese with English abstract*)

Kimura, T., Hasegawa, Y., Ohzawa, H., Yamaoka, T., Furukawa, Y., Ueda, T. *et al.*, 2007: A mysticete whale (Cetacea) skeleton from the Middle Miocene Bihoku Group, Shobara, Hiroshima, Japan.

Miscellaneous Reports of the Hiwa Museum for Natural History, vol. 48, p. 1–10. (*in Japanese with English abstract*)

Kimura, T., Hasegawa, Y., Ohzawa, H., Yamaoka, T., Ueda, T., Kiyoshi, T. *et al.*, 2011: An additional fossil mysticete from the middle Miocene Bihoku Group, Hiroshima, Japan. *Bulletin of Gunma Museum of Natural History*, vol. 15, p. 81–92. (*in Japanese with English abstract*)

Kimura, T. and Kaede, T., 2016: A well preserved odontocete forelimb from the lower Miocene Ichishi Formation, Mie Prefecture, Japan. *Bulletin of Gunma Museum of Natural History*, vol. 20, p. 79–84. (*in Japanese with English abstract*)

Kiyoshi, T., Ohzawa, H. and Yamaoka, T., 2020: Baleen whale fossils from the Bihoku Group (Miocene) in Shobara City, Hiroshima Prefecture. *Journal of the Hiba Society of Natural History*, vol. 269, p. 1–7. (*in Japanese with English abstract*)

Kohno, N., Koike, H. and Narita, K., 2007: Outline of fossil marine mammals from the Middle Miocene Bessho and Aoki Formations, Nagano Prefecture, Japan. *Research Report of the Shinshushinmachi Fossil Museum*, vol. 10, p. 1–45. (*in Japanese*)

Kohno, N. and Ray, C. E., 2008: Pliocene walruses from the Yorktown Formation of Virginia and North Carolina, and a systematic revision of the North Atlantic Pliocene walruses. *Virginia Museum of Natural History Special Publication*, vol. 14, p. 39–80.

Lambert, O., 2004: Systematic revision of the Miocene long-snouted dolphin *Eurhinodelphis longirostris* du Bus, 1872 (Cetacea, Odontoceti, Eurhinodelphinidae). *Bulletin de l'Institut Royal Des Sciences Naturelles de Belgique*, *Sciences de La Terre*, vol. 74, p. 147–174.

Lambert, O., de Muizon, C. and Bianucci, G., 2015: A new archaic homodont toothed cetacean (Mammalia, Cetacea, Odontoceti) from the early Miocene of Peru. *Geodiversitas*, vol. 37, p. 79–108.

Lambert, O., de Muizon, C., Malinverno, E., Celma, C. D., Urbina, M. and Bianucci, G., 2017: A new odontocete (toothed cetacean) from the Early Miocene of Peru expands the morphological disparity of extinct heterodont dolphins. *Journal of Systematic Palaeontology*, vol. 16, p. 1–36.

Lambert, O., Godfrey, S. J. and Fitzgerald, E. M., 2018: *Yaquinacetus meadi*, a new latest Oligocene–early Miocene dolphin (Cetacea, Odontoceti, Squaloziphiidae, fam. nov.) from the Nye Mudstone (Oregon, USA). *Journal of Vertebrate Paleontology*, vol. 38, e1559174.

Lydekker, L., 1894: Cetacean skulls from Patagonia. *Anales Del Museo de La Plata*, vol. 2, p. 1–13.

Makiyama, J., 1936: *Sinanodelphis izumidaensis*, a new Miocene dolphin of Japan. *Memoirs of the College of Science, Kyoto Imperial University. Ser. B*, vol. 11, p. 115–134.

Marx, F. G., Coste, A., Richards, M. D., Palin, J. M. and Fordyce, R. E., 2024: Strontium isotopes reveal a globally unique assemblage of Early Miocene baleen whales. *Journal of the Royal Society of New Zealand*, vol. 54, p. 711–721.

Marx, F. G., Fitzgerald, E. M. and Fordyce, R. E., 2019: Like phoenix from the ashes: How modern baleen whales arose from a fossil "dark age". *Acta Palaeontologica Polonica*, vol. 64, p. 231–238.

Marx, F. G., Lambert, O. and Uhen, M. D., 2016: *Cetacean Paleobiology*, 336 p. Wiley-Blackwell, West Sussex.

Matsuhashi, Y. and Ooyagi, K., 2013: Some fossil mammals from the Miocene Ichishi-Group, Yanaitani, Misato-Cho, Tsu-City, Mie Prefecture, central Japan. *Kaseki No Tomo*, vol. 58, p. 14–23. (*in Japanese*)

Matsumoto, H., 1926: On some fossil cetaceans of Japan. *Science Reports of the Tohoku Imperial University*, *2nd Series*, *Geology*, vol. 10, p. 17–27.

Mead, J. G. and Fordyce, R. E., 2009: The therian skull: a lexicon with emphasis on the odontocetes. *Smithsonian Contributions to Zoology*, vol. 627, p. 1–248.

Nakano, Y., 1999: Selachian fauna from the Miocene Bihoku Group in Shobara area, Hiroshima Prefecture, southwest Japan. *Geoscience Report of Shimane University*, vol. 18, p. 109–125. (*in Japanese with English abstract*)

Nelson, M. D. and Uhen, M. D., 2018: First occurrence of a squalodelphinid (Cetacea, Odontoceti) from the early Miocene of Washington State. *Journal of Vertebrate Paleontology*, vol. 38, e1428197.

Ohzawa, H., Furukawa, Y. and Yamaoka, T., 2001: A whale scapula from the Bihoku Group (Miocene) in Shobara City, Hiroshima Prefecture. *Journal of the Hiba Society of Natural History*, vol. 201, p. 46–48. (*in Japanese*)

Ohzawa, H., Kiyoshi, T., Ueda, T. and Yamaoka, T., 2013: Newly discovered hyoid bone fossil of *Parietobalaena yamaokai* (Paratype) from the Miocene Bihoku Group, Shobara City Hiroshima Prefecture. *Journal of the Hiba Society of Natural History*, vol. 246, p. 21–24. (*in Japanese with English abstract*)

Ohzawa, H., Ueda, T., Yamaoka, T., Furukawa, Y., Sugihara, M., Kiyoshi, T. *et al.*, 2007: Cetothere fossil from the Miocene Bihoku Group, Shobara, Hiroshima Prefecture, Japan. *Journal of the Hiba Society of Natural History*, vol. 225, p. 1–8. (*in Japanese with English abstract*)

Ohzawa, H. and Yamaoka, T., 2003: Fossils of mandibles of whales from the Miocene Bihoku Group, Shobara City, Hiroshima Prefecture. *Journal of the Hiba Society of Natural History*, vol. 211, p. 33–37. (*in Japanese*)

Oishi, M. and Hasegawa, Y., 1995: A list of fossil cetaceans in Japan. *Island Arc*, vol. 3, p. 493–505.

Okazaki, Y., 1976: Miocene long-snouted porpoises from the Mizunami Group, Central Japan. *Bulletin of the Mizunami Fossil Museum*, vol. 3, p. 25–39.

Okazaki, Y., 1992: An occurrence of a fossil sperm whale from the Miocene Mizunami Group, central Japan. *Bulletin of Mizunami Fossil Museum*, vol. 19, p. 295–299.

Otsuka, H., 2008: Middle Miocene Cetacean fossils from Kimita district, Hiroshima Prefecture, West Japan. *Miscellaneous Reports of the Hiwa Museum for Natural History*, vol. 49, p. 67–75. (*in Japanese with English abstract*)

Otsuka, H. and Ota, Y., 2008: Cetotheres from the early Middle Miocene Bihoku Group in Shobara District, Hiroshima Prefecture, West Japan. *Miscellaneous Reports of the Hiwa Museum for Natural History*, vol. 49, p. 1–66. (*in Japanese with English abstract*)

Peredo, C. M., Uhen, M. D. and Nelson, M. D., 2018: A new kentriodontid (Cetacea: Odontoceti) from the early Miocene Astoria Formation and a revision of the stem delphinidan family Kentriodontidae. *Journal of Vertebrate Paleontology*, vol. 38, e1411357.

Pilleri, G., 1985: The Miocene Cetacea of the Belluno sandstones (eastern southern Alps). *Memorie di Scienze Geologiche*, vol. 37, p. 1–250.

Sanders, A. E. and Geisler, J. H., 2015: A new basal odontocete from the upper Rupelian of South Carolina, U.S.A., with contributions to the systematics of *Xenorophus* and *Mirocetus* (Mammalia, Cetacea). *Journal of Vertebrate Paleontology*, vol. 35, e890107.

Seto, K. and Yamauchi, S., 2009: Miyoshi–Shobara district, Hiroshima. *In*, Nishimura, Y. and Kiminami, K. *eds.*, *Regional Geology of Japan 6 Chugoku Region [Nihon chiho chishitsushi 6 Chugoku chiho]*, p. 136–138. Asakura Shoten, Tokyo. (*in Japanese*)

Shikama, T., 1975: Mammalia. *In*, Shikama, T. *ed.*, *Paleontology III*, p. 334–475. Asakura Shoten, Tokyo. (*in Japanese*)

Tanaka, Y. and Fordyce, R. E., 2015: A new Oligo-Miocene dolphin from New Zealand: *Otekaikea huata* expands diversity of the early

Platanistoidea. *Palaeontologia Electronica*, 18.2.23A.
Tanaka, Y. and Fordyce, R. E., 2016: *Papahu*-like fossil dolphin from Kaikoura, New Zealand, helps to fill the Early Miocene gap in the history of Odontoceti. *New Zealand Journal of Geology and Geophysics*, vol. 59, p. 551–567.
Tanaka, Y. and Nakagawa, R., 2024: A new platanistoid (Odontoceti: Squalodelphinidae) from the Early Miocene of Japan. *Journal of Systematic Palaeontology*, vol, 22. p. 1–28.
Tanaka, Y., Ohara, M. and Kimura, T., 2021: A fossil dolphin from the Oi Formation, Ichishi Group (late early Miocene) in Japan. *Paleontological Research*, vol. 25, p. 19–24.
Tanaka, Y., Ortega, M. E. and Fordyce, R. E., 2023: A new early Miocene archaic dolphin (Odontoceti, Cetacea) from New Zealand, and brain evolution of the Odontoceti. *New Zealand Journal of Geology and Geophysics*, vol. 66, p. 59–73.
Tanaka, Y., Yamaoka, T., Ohzawa, H. and Kiyoshi, T., 2020: A short note of a possible toothed whale humerus from the Korematsu Formation, Bihoku Group (lower to middle Miocene) in Shobara, Hiroshima, Japan. *Miscellaneous Reports of the Hiwa Museum for Natural History*, vol. 62, p. 1–7.
Tsai, C.-H., 2017: A Miocene breeding ground of an extinct baleen whale (Cetacea: Mysticeti). *PeerJ*, vol. 5, e3711.
Viglino, M., Buono, M. R., Fordyce, R. E., Cuitiño, J. I. and Fitzgerald, E. M., 2019: Anatomy and phylogeny of the large shark-toothed dolphin *Phoberodon arctirostris* Cabrera, 1926 (Cetacea: Odontoceti) from the early Miocene of Patagonia (Argentina). *Zoological Journal of the Linnean Society*, vol. 185, p. 511–542.
Viglino, M., Buono, M. R., Gutstein, C. S., Cozzuol, M. A. and Cuitiño, J. I., 2018: A new dolphin from the early Miocene of Patagonia, Argentina: Insights into the evolution of Platanistoidea in the Southern Hemisphere. *Acta Palaeontologica Polonica*, vol. 63, p. 261–277.
Viglino, M., Buono, M. R., Tanaka, Y., Cuitiño, J. I. and Fordyce, R. E., 2022: Unriddling an old dolphin: platanistoid *Notocetus vanbenedeni* Moreno, 1892 from the early Miocene of Patagonia (Argentina). *Journal of Systematic Palaeontology*, vol. 20, p. 1–41.
Viglino, M., Gaetán, C. M., Cuitiño, J. I. and Buono, M. R., 2020: First toothless platanistoid from the Early Miocene of Patagonia: the golden age of diversification of the Odontoceti. *Journal of Mammalian Evolution*, vol. 21, p. 337–358.
Yamamoto, Y., 1999: Lithofacies and calcareous nannofossils of the Miocene Bihoku Group in the Saijogawa area, Shobara, Hiroshima, Japan. *Earth Science*, vol. 53, p. 202–216. (*in Japanese with English abstract*)
Yamaoka, T., 1995: A shark tooth embedded in the ulna of a fossil whale from Shobara. *Journal of the Hiba Society of Natural History*, vol. 164, p. 63–64. (*in Japanese*)
Yoshida, K., Kimura, T. and Hasegawa, Y., 2003: New cetothere (Cetacea: Mysticeti) from the Miocene Chichibumachi Group, Japan. *Bulletin of the Saitama Museum of Natural History*, vol. 20, p. 1–10. (*in Japanese with English abstract*)

Author contributions

Y. T. conceptualized this study and wrote the original draft. T. K. made Table 3. T. Y., H. O. and T. K. contributed discussion and revised the draft.