

# Whale fossils from the lower Miocene, Yoshino Formation, Katsuta Group, Okayama, Japan

Yoshihiro TANAKA<sup>1,2,3,4)\*</sup>

## Abstract

Five fossil whale bones discovered by Mr. Shingo Kishimoto from the Yoshino Formation, Early Miocene are identified as below. MNHAH D1-059542 is a left tympanic bulla (cf. *Isanacetus laticephalus*). MNHAH D1-059543 is a fragmentary cranium (Chaemysticeti indet.). MNHAH D1-059544 to 059546 are three vertebrae belonging to one individual (Cetacea indet.). These additional specimens supplement knowledge of Early to Middle Miocene whales in the region, and to compare with other areas for the future studies.

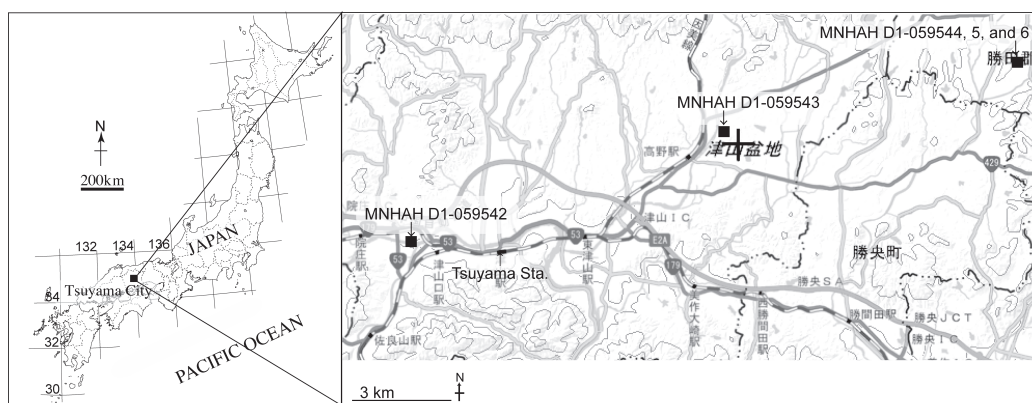
**Keywords:** baleen whale, Early Miocene, *Isanacetus laticephalus*, skull, tympanic bulla, vertebrae.

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## INTRODUCTION

Five fragmentary whale bones were collected from Okayama, Japan (Fig. 1, Table 1) by Mr. Shingo Kishimoto, including a tympanic bulla reported by him as Mysticeti indet. (Kishimoto, 2022). Mr.

Kishimoto deposited the specimens to the Museum of Nature and Human Activities, Hyogo (MNHAH), Japan in late 2022, and encouraged studying those specimens. Here, I present a short note of descriptions on the three specimens, and comparison with other supposed related taxa.



**Fig. 1.** Maps showing the locality of MNHAH D1-059542 to 059546. The base map (right) is from the topographic map published by the Geospatial Information Authority of Japan. Left map is modified from Tanaka and Taruno (2022).

<sup>1)</sup> Sapporo Museum Activity Center, 5-15-1-6, Hiragishi, Toyohira-ku, Sapporo-shi, Hokkaido, 062-0935, Japan  
<sup>2)</sup> Osaka Museum of Natural History, 1-23, Nagai Park, Higashi-Sumiyoshi-ku, Osaka-shi, Osaka, 546-0034, Japan  
<sup>3)</sup> Hokkaido University Museum, Kita 10-jou, Nishi 8-chome, Kita-ku, Sapporo-shi, Hokkaido, 060-0810, Japan  
<sup>4)</sup> Numata Fossil Museum, 6-493 Nishi-machi, Numata-cho, Uryu-gun, Hokkaido, 078-2204, Japan

\* Corresponding author. E-mail: yoshi.tanaka.res@gmail.com

**Table 1.** Studied materials.

Specimen number	Element	Longitude and latitude	Date	Identification in this study
MNHAH D1-059542	Left tympanic bulla	N35°03'25.3", E133°58'24.6"	21 Aug. 1994	<i>cf. Isanacetus laticephalus</i>
MNHAH D1-059543	Cranium	N35°05'17.6", E134°04'48.5"	17 Sep. 1995	Chaemysticeti indet.
MNHAH D1-059544	Vertebra	N35°06'43.3", E134°11'34.2"	4 Jan. 1992	Cetacea indet.
MNHAH D1-059545	Vertebra	N35°06'43.3", E134°11'34.2"	4 Jan. 1992	Cetacea indet.
MNHAH D1-059546	Vertebra	N35°06'43.3", E134°11'34.2"	4 Jan. 1992	Cetacea indet.

## METHODS

Morphological terms follow Mead and Fordyce (2009) for the cranium and tympanic bulla. Surfaces are eroded in places, noted when major.

## RESULTS

Order Cetacea Brisson, 1762

Unranked taxon Neoceti Fordyce and de Muizon, 2001

Suborder Mysticeti Cope, 1891

Unranked taxon Chaemysticeti Mitchell, 1989

Incertae familiae

*Isanacetus laticephalus* Kimura and Ozawa, 2002  
*cf. Isanacetus laticephalus*

*Referred material.*—MNHAH D1-059542 is a left tympanic bulla. It was identified as Mysticeti indet. previously (Kishimoto, 2022).

*Remarks.*—MNHAH D1-059542 is most similar to *Isanacetus laticephalus* known only from Japan (Kimura et al., 2018; Kimura and Ozawa, 2002; Tanaka et al., 2023), based on the following combination of features: a squared anterior margin in medial view, well posteriorly projected outer posterior prominence, and posteriorly abruptly projecting involucrum in dorsal view (see more in discussion).

*General description.*—The tympanic bulla MNHAH D1-059542 (Fig. 2 and Table 2) is long. In medial view (Fig. 2 C and D), the anterior end is squared, and posterior part is damaged medially.

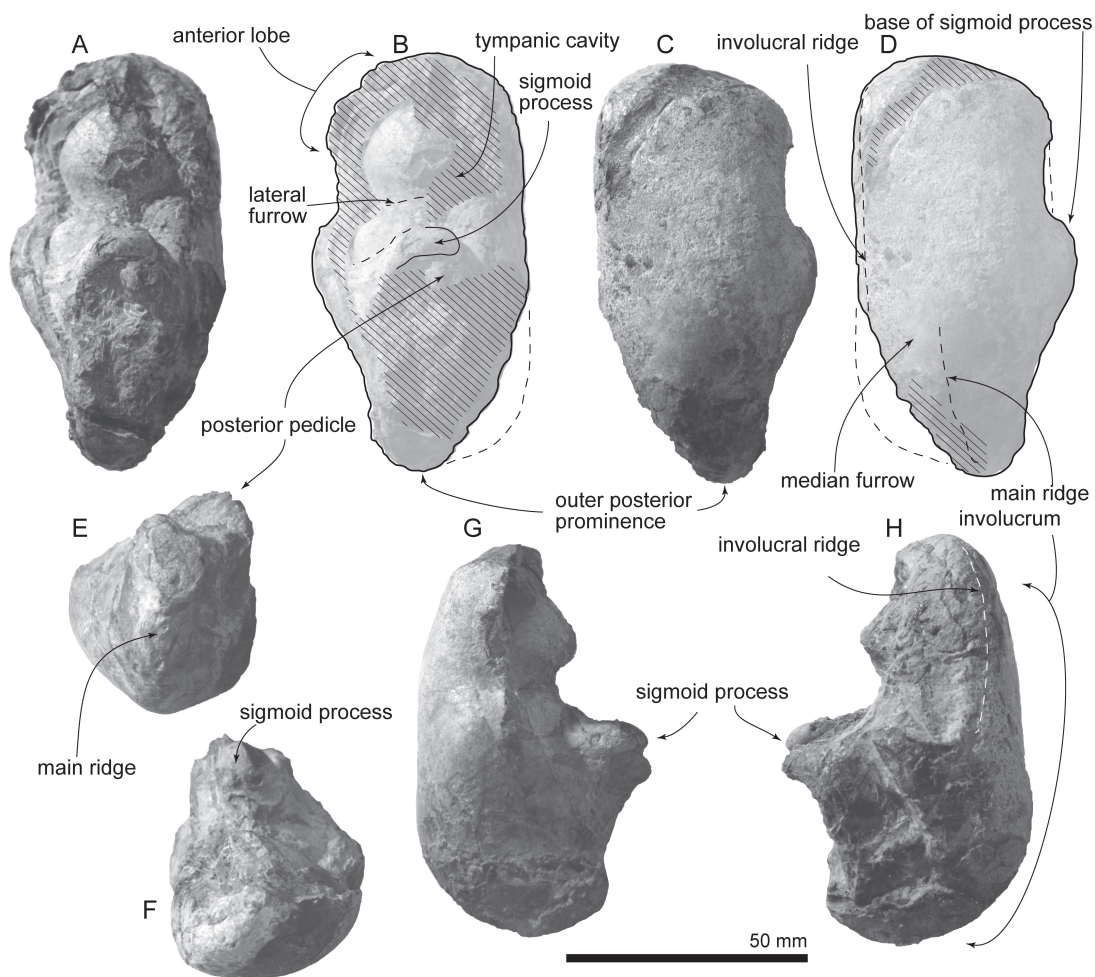
The lateral part of the tympanic bulla is collapsed and displaced into the tympanic cavity. The posterior pedicle projects laterally, and it continues to the lateral margin of the involucrum. In dorsal view (Fig. 2 H), the involucrum is anteriorly low but prominent posteriorly. Just anterior to the posterior pedicle, there is the sigmoid process, which is a narrow U-shape in anterior view. Anterior to the sigmoid process, there is a shallow lateral furrow. The main ridge is well-developed. Dorsal to the main ridge, a faint involucral ridge runs to the anterior tip of the tympanic bulla. Medial to the outer posterior prominence, the median furrow is a faint and flat area, but its shape cannot be recognized well owing to damage of the posteromedial part of the tympanic bulla and the anteriorly faint main ridge.

*Locality.*—MNHAH D1-059542 was found at the riverbed of the Yoshii River in a calcareous nodule (N35°03'25.3", E133°58'24.6") in 21 Aug 1994 (Fig. 1).

*Referred material.*—MNHAH D1-059543 is a fragmentary cranium including the pterygoid, squamosal and basioccipital.

**Table 2.** Measurements (mm) of the left tympanic bulla MNHAH D1-059542 *cf. Isanacetus laticephalus*.

Bulla	
Greatest length, in lateral view	83.5
Greatest width, in lateral view	42.0
Greatest height, from tip of sigmoid process to the ventral-most point in posterior view	50.5
Length of anterior lobe, from lateral furrow to anterior tip of tympanic bulla	25.5



**Fig. 2.** Left bulla of cf. *Isanacetes laticephalus* (MNHAH D1-059542): (A) lateral view, (B) lateral view with key features, (C) medial view, (D) medial view with key features, (E) posterior view, (F) anterior view, (G) ventral view, and (H) dorsal view.

*Remarks.*—This cranium shows an anteroposteriorly short pterygoid sinus fossa, which is restricted by a bony wall of the pterygoid anteromedially and the cranial hiatus posteriorly. This condition of the pterygoid sinus fossa is not shared with toothed mysticetes, where the pterygoid sinus is deep (Barnes et al., 1995; Deméré and Berta, 2008; Fordyce and Marx, 2018). Among the Chaemysticeti, MNHAH D1-059543 differs from the Eomysticetidae and Balaenopteridae by having an anteroposteriorly short pterygoid sinus fossa (Sanders and Barnes, 2002; Tanaka and Watanabe, 2019).

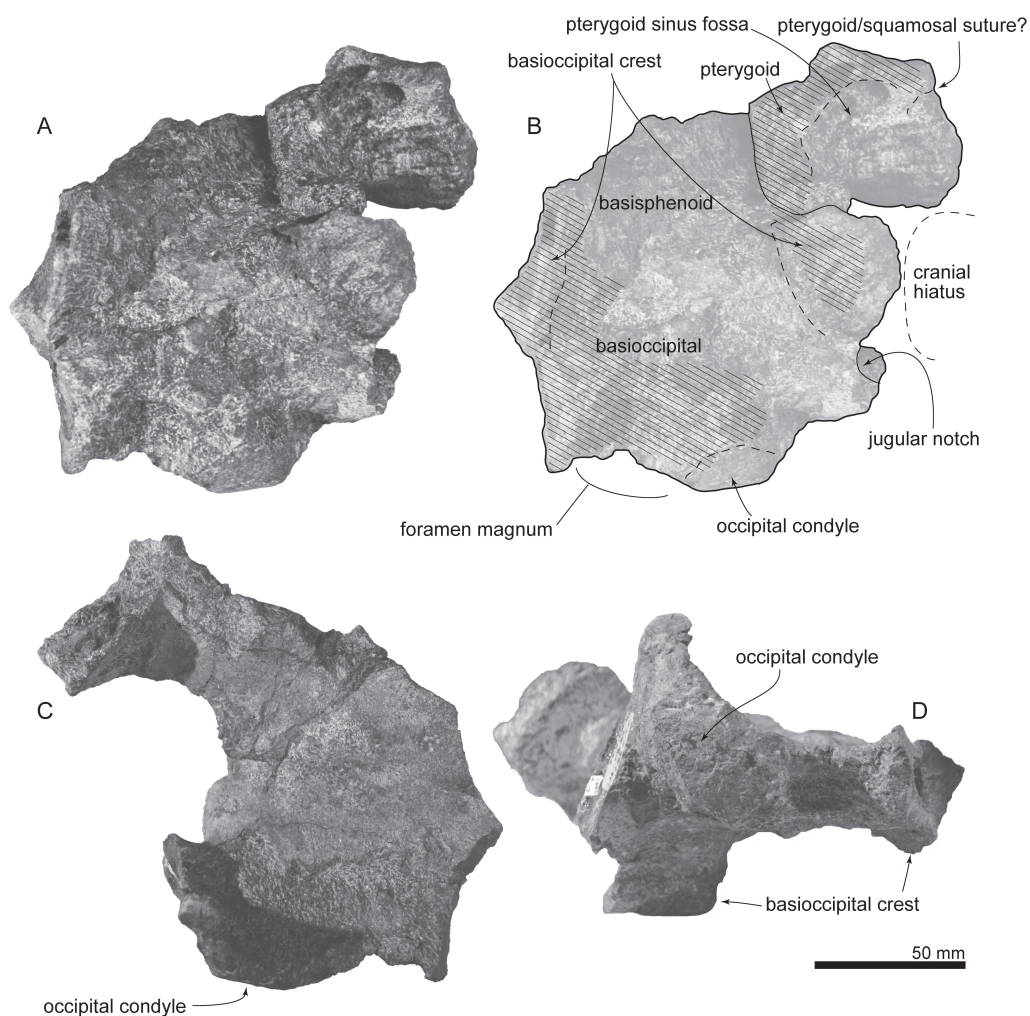
*General description.*—A fragmentary basicranium MNHAH D1-059543 (Fig. 3) includes the pterygoid, squamosal and basioccipital. In the basioccipital, the occipital condyle is relatively flat, does not project posteriorly, dorsally narrow, ventrally wide and

laterally swollen (the left basioccipital condyle is 55 mm height, 41 mm wide). Anterior to the basioccipital, the transversely wide basioccipital crest projects ventrolaterally. Posteromedial to the basioccipital crest, there is the jugular notch running dorsoventrally. The basioccipital crest continues anteriorly and forms the medial border of a shallow and anteroposteriorly short pterygoid sinus fossa (52 mm wide, 26 mm long). At the anterolateral margin of the pterygoid sinus fossa, there is a small gap, which might be the pterygoid/squamosal border.

*Locality.*—MNHAH D1-059543 was found at a construction site (N35°05'17.6", E134°04'48.5") on 17 Sep 1995 (Fig. 1).

*Referred materials.*—MNHAH D1-059544 to 059546, three associated vertebrae.





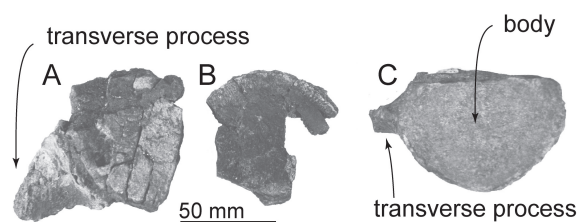
**Fig. 3.** Cranium of *Chaecomysticeti* indet.: (A) ventral view, (B) ventral view with key features, (C) dorsal view, (D) posterior view.

*Remarks.*—These vertebrae belong to a single individual because they were discovered from a single block. Broken surfaces reveal spongy bone, which imply these bones belong to a Cetacea.

*General description.* —Three small vertebrae (MNHAH D1-059544, 5, and 6) are preserved (Fig. 4). MNHAH D1-059545 (vertebra A in Fig. 4) measures 96 mm in width, height: 70 mm and length: 26 mm. The epiphyses are fused to the body. The transverse process projects ventrally from a relatively lower position. They imply that the vertebra A may be a cervical vertebra. MNHAH D1-059546 (vertebra B in Fig. 4) measures 65 mm in width, 65 mm in height and 18 mm in length. The vertebra B preserves the body but the vertebral epiphyses are broken away. MNHAH D1-059544 (vertebra C in Fig. 4) measures 90 mm in width, 55

mm in height and 60 mm in length. An anterior or posterior side of the body preserves the ventral part. The epiphysis is fused to the body. The transverse process projects laterally from a high position.

*Locality.*— MNHAH D1-059544 to 059546 were found at a construction site in Nishibara (N35°06'43.3", E134°11'34.2") in 4 Jan 1992 (Fig. 1).



**Fig. 4.** Three vertebrae of *Cetacea* indet. (A) MNHAH D1-059545, (B) MNHAH D1-059546, (C) MNHAH D1-059544.

## Horizon and age

All specimens were derived from the Yoshino Formation, Katsuta Group. The age of the Katuta Group is considered Early to Middle Miocene (Sawada, 2009). Tuff layers in the Yoshino and Takakura Formations were examined a fission track age as  $17.9 \pm 2.1$  Ma  $16.2 \pm 2.1$  Ma respectively (Suzuki et al., 2003). Diatom fossils from the middle part of the Takakura Formation was corresponded to the upper *Crucidentacula kanayae* Zone (NPD 3A, 16.9 to 16.3 Ma) or the lower *Denticulopsis praelauta* Zone (NPD 3B, 16.3 to 15.9 Ma) (Watanabe et al., 1999). The molluscan fauna of the Yoshino Formation belongs to the Early Middle Miocene Kurosedani fauna (Taguchi, 2002). A study of wider stratigraphic correlation study based on magnetostratigraphy and biostratigraphy suggested that the Yoshino Formation is about 17 to 16.5 Ma (Irizuki et al., 2021). Thus the specimens represent whales from the late Early Miocene (late Burdigalian).

## DISCUSSION

There are several named Early to Middle Miocene baleen whales in Japan; *Isanacetus laticephalus* from Mie (Kimura and Ozawa, 2002), *Jobancetus pacificus* from Fukushima (Kimura et al., 2023), *Diorocetus chichibuensis* from Saitama (Kimura et al., 2000; Yoshida et al., 2003), *Diorocetus shobarensis* and *Parietobalaena yamaokai* from Hiroshima (Otsuka and Ota, 2008), and *Taikicetus inouei* from Hokkaido (Tanaka et al., 2018). A specimen identified as *Pelocetus* sp. is known from Hiroshima (Kimura et al., 2007).

The tympanic bulla MNHAH D1-059542 is most similar to that of *Isanacetus laticephalus*. Having a square anterior portion in medial view is shared by MNHAH D1-059542, *I. laticephalus*, *D. chichibuensis*, *T. inouei* and GMNH-PV-2317, which was identified as a cetotheriid (Kimura et al., 2008). On the other hand, *J. pacificus* and *Pelocetus* sp. have rounded, and *P. yamaokai* and *D. shobarensis* have acute anterior portions of the tympanic bullae in medial view. Having an anteriorly low but posteriorly prominent involucrum in dorsal view is shared by

MNHAH D1-059542, *I. laticephalus*, *J. pacificus*, *Pelocetus* sp. and *P. yamaokai*. On the other hand, GMNH-PV-2317, *D. chichibuensis*, and *T. inouei* show involucra which gradually rise in dorsoventral height/depth.

The skull MNHAH D1-059543 is fragmentary and comparisons are limited. Compared to those baleen whales from Japan, MNHAH D1-059543, *D. chichibuensis* and *I. laticephalus* also possess anteroposteriorly short pterygoid fossae. MNHAH D1-059543 is much smaller than the skull of *Pelocetus* sp. However, this does not mean that MNHAH D1-059543 belongs to one of these taxa. It can not be identified further more because of its limited preservation.

## CONCLUSION

Five fossil whale bones from the Yoshino Formation, Early Miocene are identified as below. MNHAH D1-059542 is a left tympanic bulla (cf. *Isanacetus laticephalus*). MNHAH D1-059543 is a fragmentary cranium (*Chaecomysticeti* indet.). MNHAH D1-059544 to 059546 are three vertebrae belonging to one individual (*Cetacea* indet.). Abundant fossils have been discovered at this locality, but only few of them have been reported (Kimura et al., 2008; Kishimoto, 2022). In the future, more specimens will be helpful to recognize what sort of whales lived during the Early to Middle Miocene at the area and to compare with other areas.

## Acknowledgments

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## Competing interests

There are no conflicts of interest with any specific company in conducting this study.

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## 岡山県の勝田層群吉野層より産出した鯨類化石

吉野層より岸本眞五氏によって発見された 5 つの鯨類化石骨が次のように同定された。兵庫県立人と自然の博物館の標本番号 MNHAH D1-059542 は左鼓室胞 (cf. *Isanacetus laticephalus*). MNHAH D1-059543 は断片的な頭蓋骨 (*Chaecomysticti* indet.). MNHAH D1-059544 から 059546 は 1 個体に由来する 3 つの脊椎骨 (Cetacea indet.). これらの標本によって、該当地域の前期から中期中新世にかけての鯨類についての知識を追加した。

**キーワード:** 鼓室胞, 頭蓋骨, 脊椎骨, 前期中新世, ヒゲクジラ, *Isanacetus laticephalus*.