

An early archaic-odobenid calcaneum from the lower Miocene Shukunohora Formation, Mizunami Group in Mizunami City, Gifu Prefecture, Japan

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Abstract A calcaneum specimen is reported from the lower Miocene Shukunohora Formation (approximately 16 Ma: Burdigalian), Mizunami Group in Mizunami City, Gifu Prefecture, central Japan. The present specimen is identified as Odobenidae gen. et sp. indet., and it is the third record of early archaic-odobenids in the western North Pacific. Because of this specimen from deposition in the tropical shallow-marine environment (i.e., mangrove swamps or near that environment), the discovery supports that early archaic-odobenids inhabited the tropical shallow-marine environment.

Key words: archaic odobenids, Odobenidae, early Miocene, western North Pacific region

Introduction

Odobenids are members of Pinnipeds, which are amphibious carnivores that inhabit various water-side environments (e.g. King, 1983; Riedman, 1990; Rice, 1998). *Odobenus rosmarus* (walrus) is the only extant odobenid species, which shows discontinuous distribution in areas around the North Pole; however, several extinct odobenid species shown broad distribution (e.g. Deméré, 1994a; Deméré, 1994b; Berta, 2009; Boessenecker and Churchill, 2013; Berta *et al.*, 2015; Tanaka and Kohno, 2015; Berta *et al.*, 2018). The earliest odobenids originated around the North Pacific (e.g. Deméré, 1994b; Deméré *et al.*, 2003). There are archaic-odobenids (i.e., *Prototaria* spp., *Proneotherium*, *Kamtschatarctos* and *Neotherium*) (see Tanaka and Kohno, 2015, fig. 11) from both the eastern and western North Pacific (Miyazaki *et al.*, 1994; Deméré *et al.*, 2003); however, these records are limited. The oldest records of odobenids are *Pelagiarctos* and the early archaic-odobenid *Proneotherium* from the late early Miocene (Burdigalian) in the eastern North Pacific (USA) (Barnes, 1988; Kohno *et al.*, 1995; Deméré and Berta, 2001; Boessenecker and Churchill, 2013). In Japan, *Prototaria* spp. from the early middle Miocene (N9 of

Blow, 1969) Shimo Formation of Fukui, and the latest early to early middle Miocene (N8 of Blow, 1969) Moniwa Formation of Miyagi, are the oldest fossil-odobenids records, and the genus is the only early archaic-odobenids (Takeyama and Ozawa, 1984; Kohno, 1994). Therefore, to unravel the early evolution of odobenids around the North Pacific, more specimens are required from early archaic-odobenids during the late early to early middle Miocene.

In this study, we studied the pinniped specimen from the lower Miocene Shukunohora Formation (approximately 16 Ma: Burdigalian), Mizunami Group, Gifu, Japan and housed in Mizunami Fossil Museum. This specimen was identified as Otariidae gen. et sp. indet. by Kohno (1992, table 2). However, it was not based on an evidence of morphological description. Therefore, in this paper, we identified this specimen based on the morphological description in detail. This specimen represents early archaic-odobenids in the western North Pacific.

Material and methods

The following specimen of pinnipeds MFM 180114 from the lower Miocene Shukunohora Formation, Mizunami Group, Gifu, Japan was exam-

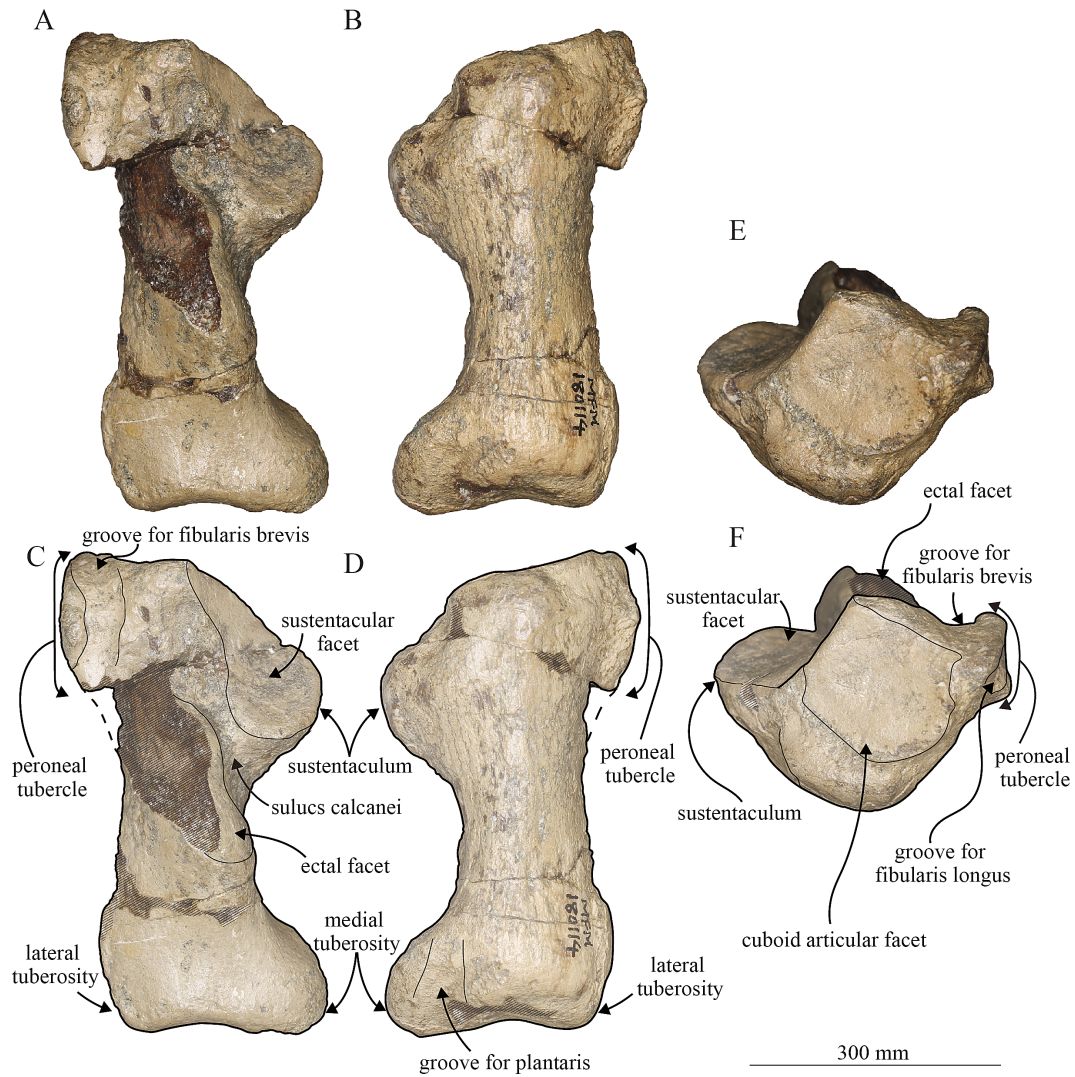


Fig. 1. *Odobenidae* gen. et sp. indet., left calcaneum, MFM 180114. A, C, talocalcaneal view; B, D, plantar view; E, F, anterior view. Dashed lines indicate missing parts.

Table 1. Measurements in mm of the calcaneum (MFM 180114).

	MFM 180114
Maximum anteroposterior length	59.8
Maximum transverse width	31.1
Maximum dorsoplantar height	25.5
Transverse width between medial to lateral tuberosity	27.2
Anteroposterior length of sustentaculum (between anterior end of body and posterior end of sustentaculum)	21.5
Anteroposterior length of peroneal tubercle	14.7
Anteroposterior length of calcaneal tuber (between posterior end of ectal facet to posterior end of body)	19.3
Width of sulcus calcanei	3.1

ined personally for description and comparison. The specimen was photographed with a DSLR camera (Canon EOS Kiss X50) and measured with a digital caliper (Mitutoyo CD-20APX). Anatomical termi-

nology follows that of Deméré and Berta (2001).

Institutional abbreviations—MFM, Mizunami Fossil Museum, Gifu, Japan; NMNS, National Museum of Nature and Science, Ibaraki, Japan; USNM, National Museum of Natural History and Culture, Smithsonian Institution, Washington D. C., USA.

Systematic Paleontology

Class Mammalia Linnaeus, 1758

Order Carnivora Bowditch, 1821

Family *Odobenidae* Allen, 1880

Odobenidae gen. et sp. indet.

(Figure 1, Table 1)

Otariidae gen. et sp. indet. Kohno, 1992: table 2.

Referred specimen: MFM 180114, left calcaneum collected by T. Fushimi in 1977 (Kohno, 1992).

Locality and horizon: The locality is Oginoshima, Kamado-cho, east of Mizunami City, Gifu, Japan (Kohno, 1992). The present specimen was collected from the Shukunohora Formation (approximately 16 Ma: Burdigalian), Mizunami Group (Itoigawa and Shibata, 1992; Kohno, 1992; Saito *et al.*, 1995; Irizuki and Hosoyama, 2006; Hoshi *et al.*, 2015).

Remarks: The prominent medial tuberosity is a derived character in Odobenidae (Berta and Wyss, 1994: character 125; Deméré and Berta, 2001, character 22).

Description: MFM 180114 is a relatively small calcaneum (59.8 mm anteroposterior length and 31.1 mm transverse width). The cuboid articular facet is nearly a rhombus with rounded corners in anterior view. The peroneal tubercle, having the groove for the fibularis brevis and longus, is moderate (14.7 mm anteroposterior length) and laterally developed. The long axis of the peroneal tubercle is slightly deflected to the planta. The sustentaculum is moderate (21.5 mm anteroposterior length), has no secondary shelf (see Robinette and Stains, 1970, fig. 1) as Otariidae. The sustentacular facet is shaped like a tear-drop that is anteroposteriorly long. The sulcus calcanei between the sustentacular and ectal facets is moderate (3.1 mm width). The ectal facet is almost broken. The calcaneal tuber is moderate (19.3 mm anteroposterior length). The lateral tuberosity is small. The medial tuberosity is well developed, projecting medial-posteriorly. The latter tuberosity is more medially projecting than a medial end of the sustentaculum. The posterior border of between former and latter tuberosity is slightly concave; however, it is not a distinctive groove. The groove for the plantaris is not very distinctive; however, it is relatively wide and is tilted along by the medial tuberosity.

Comparison and discussion

The anteroposterior length of the calcaneum, MFM 180114 is approximately the same as that of the living otariid, male-adult brown fur seal (*Arctocephalus pusillus*); however, the body is sharper than that of *A. pusillus*. The cuboid articular facet forming a rhombus with rounded corners is the

same character as in the referred calcanei of the archaic-odobenid *Neotherium* (USNM 11542) and the early archaic-odobenid *Proneotherium* (USNM 335526). The secondary shelf of the sustentaculum is a synapomorphy of extant otariids (Robinette and Stains, 1970; Berta and Wyss, 1994; Velez-Juarbe, 2017); however, that of MFM 180114 is absent. The sustentacular facet is anteroposteriorly short in phocids (Robinette and Stains, 1970); however, it is shaped like a tear-drop that is anteroposteriorly long in MFM 180114. The long calcaneal tuber is a primitive character seen in *Potamotherium* (NMNS-PV 20878), which is a sister group of pinnipedimorpha (e.g. Yonezawa *et al.*, 2008; Poust and Boessenecker, 2017). The moderate calcaneal tuber, which is the condition of MFM 180114, is seen in the earliest pinnipedimorph *Enaliarctos* (USNM 374272), *Neotherium*, *Proneotherium*, and phocids (Robinette and Stains, 1970). The medial tuberosity of MFM 180114 is well-developed and more medially projecting than a medial end of the sustentaculum, which the condition of the medial tuberosity such as this specimen is the same as extinct odobenids *Proneotherium* and *Imagotaria* (USNM 23862), and the prominent medial tuberosity is a derived character in Odobenidae (Berta and Wyss, 1994: character 125; Deméré and Berta, 2001, character 22). From the above, the calcaneum, MFM 180114 is identified as Odobenidae gen. et sp. indet., and this specimen probably belongs early archaic-odobenids, because it has same characters seen in the group.

Until now, because the only early archaic-odobenid was *Prototaria* spp. found in the Shimo Formation of Fukui and the Moniwa Formation of Miyagi, Japan (Takeyama and Ozawa, 1984; Kohno, 1994), the specimen is the third record of early archaic-odobenids in the early to early middle Miocene western North Pacific. In early archaic-odobenids, *Prototaria* spp. were known from deposition in the shallow marine and warm to tropical temperature zones (Takeyama and Ozawa, 1984; Kitamura *et al.*, 1986; Kohno, 1994), and *Proneotherium* was known from deposition in the shallow marine and warm to sub-tropical temperature zones (Deméré and Berta, 2001). The Shukunohora Formation containing the present specimen is also deposition in the tropical shallow-marine environment (i.e., man-

grove swamps or near that environment) (Itoigawa and Shibata, 1992; Saito *et al.*, 1995). Therefore, the discovery supports that early archaic-odobenids inhabited the tropical shallow-marine environment.

Acknowledgments

Thanks to T. Haga (NMNS) for help with the Shukunohora Formation information; to Y. Tajima and T. Yamada (NMNS), D. J. Bohaska, D. P. Lunde, A. Millhouse, J. Ososky and N. D. Pyenson, (USNM) for access to extant and extinct pinnipeds collection under their care. We would like to thank Y. Tanaka (Osaka Museum of Natural History) for his constructive review. This study was supported in part by the Sasakawa Scientific Research Grant from The Japan Science Society.

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