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A cervoid tooth from the lower Miocene Nakamura Formation of the Mizunami Group in Kani City, Gifu Prefecture, central Japan

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Abstract

We describe an isolated right lower third molar (M_3) of Cervoidea (Ruminantia, Artiodactyla, Mammalia) from the lower Miocene Nakamura Formation (ca. 19 Ma) of the Mizunami Group, Kani City, Gifu Prefecture, central Japan. This specimen is distinguished from M_3 of a palaeomerycid species *Amphitragulus minoensis*, which is the only named cervoid species that has been recorded in the Mizunami Group, in having smaller molars, the strong external postprotocristid, opening posterior cristids between the postentocristid and the posthypocristid. In having these characteristics, it is comparable to M_3 of a cervid species *Dicrocerus tokunagai* from the lower Miocene of northeastern Japan and *Dicrocerus* or lagomerycine cervids from the lower/middle Miocene of China.

Key words: Asia, Cervoidea, Mizunami Group, Neogene, Ruminantia

Introduction

The Miocene Mizunami Group, central Japan, is composed of freshwater to marine deposits and yields a variety of terrestrial mammal, plant, and marine vertebrate/invertebrate fossils. The terrestrial mammalian fossils from the group have been found in the lower Miocene part of the group distributed in the Kani and Mizunami basins. The terrestrial mammalian fauna of the group includes six orders: Soricomorpha (*Plesiosorex* sp.), Rodentia (*Youngofiber sinensis*, ?*Eucastor* sp., *Minocastor godai*, *Megapeomys* sp., Eomyidae gen. et sp. indet. 1, Eomyidae gen. et sp. indet. 2), Lagomorpha (*Alloptox japonicus*), Perissodactyla (*Brachypotherium pugnator*, *Plesiaceratherium* sp., *Plesiotapirus yagii, Anchitherium* aff. *gobiense*), Artiodactyla (Cervoidea fam., gen. et spp. indet., including *Amphitragulus minoensis*), and Proboscidea (*Gomphotherium annectens*) (Kamei and Okazaki, 1974; Okazaki, 1977; Okumura *et al*., 1977; Fukuchi and Kawai, 2011; Tomida, 2012; Tomida *et al*., 2013; Mörs *et al*., 2016). Among them, artiodactyl fossils are rarely found and represented only by cervoid ruminants. Furthermore, most of the cervoids from the group have not been cleared taxonomically.

To date, cervoid fossils of the Mizunami Group have been recorded from the Hachiya and Hiramaki formations (ca. 24.2–19.6 Ma and 18.4–17.0 Ma, respectively by Shikano, 2003) of the Kani basin and from the Akeyo Formation (ca. 18.3–17.0 Ma by Watanabe and Yanagisawa, 2005) of the Mizunami basin (Matsumoto, 1918; Kamei and Okazaki, 1974; Okazaki, 1977; Shikano and Ando, 2000). Many of the cervoid fossils from the Mizunami Group have been assigned to *Amphitragulus minoensis* Matsumoto, 1918, but Tomida *et al*. (2013) suggested that all cervoid fossil records from Kani and Mizunami are still uncertain taxonomically because of insufficient diagnostic material from each locality.

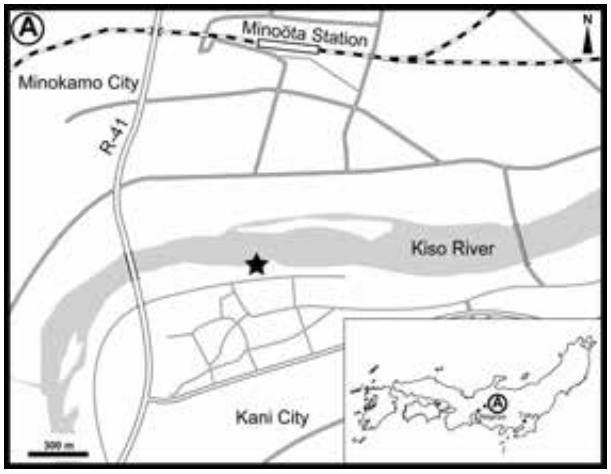


Fig. 1. Map showing the fossil locality (star mark) of the present fossil specimen (MFM18126; Cervoidea fam., gen. et sp. indet.).

Recently, an isolated cervoid tooth was collected from the Nakamura Formation of the Kani basin by T. Goda who is a member of the Mizunami Fossil Museum Friends. Here, we describe this cervoid fossil to discuss its taxonomic relationship with Oligo-Miocene ruminants from Japan and the Eurasian Continent.

Abbreviations: MFM, Mizunami Fossil Museum, Mizunami, Gifu Prefecture, Japan.

Geological settings

The cervoid tooth fossil was recovered from the Nakamura Formation that is exposed on the south riverside of the Kiso River, Dota, Kani City, Gifu Prefecture, central Japan (Fig. 1). The formation (ca. 200 m in thickness) lies between the Hachiya and Hiramaki formations, consists primarily of sandstones and mudstones, and is known in yielding plants (*e.g.*, *Metasequoia occidentalis*, *Alnus kefersteinii*, *Fagus antipofi*), mammals (*e.g.*, *Youngofiber sinensis, Minocastor godai, Brachypotherium pugnator*, *Plesiotapirus yagii, Amphitragulus minoensis*), cyprinid fishes (*e.g.*, *Cyprinus* sp.), and freshwater molluscs (*e.g.*, *Anodonta* sp., *Viviparus* sp.) (Ina, 1981; Yasuno, 1982; Okumura *et al*., 1977; Tomida *et al*., 1995; Mörs *et al*., 2016).

The fossil-bearing horizon of the cervoid tooth is the upper part composed of gray sandstone of the Nakamura Formation (Fig. 2). The middle and upper parts of the Hachiya Formation were dated at 20.6 ± 2.0 Ma and 19.8 ± 2.1 Ma, respectively, based on the K-Ar dating (Takeuchi, 1992). Moreover, the Nakamura Formation was dated at 19.6–18.4 Ma based on the fission-track dating (Shikano, 2003), and is stratigraphically correlated with the Toki Lignite-bearing Formation of the Mizunami basin, with the fission-track age ranging from 20 to 18 Ma (Sasao *et al*., 2006).

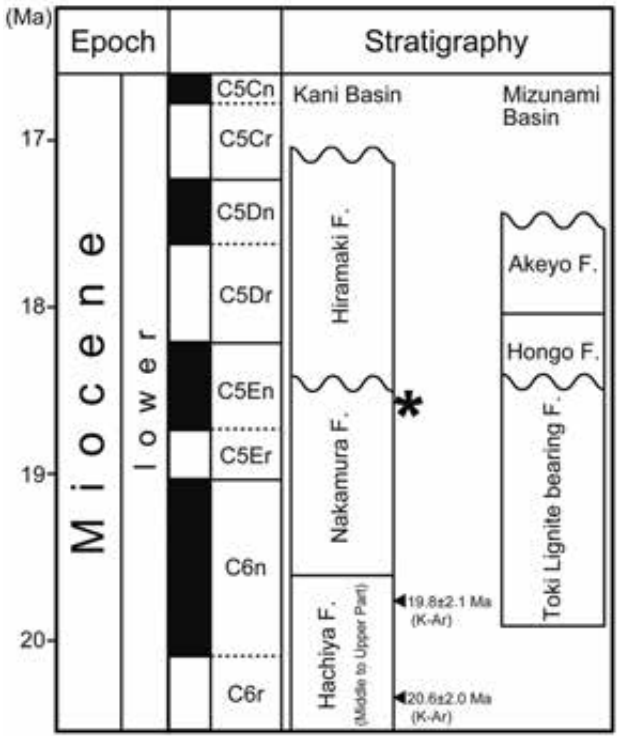


Fig. 2. Chronological relationship of the Mizunami Group between the Kani and Mizunami basins, with the fossil bearing horizon (asterisk).

Systematics

Order Artiodactyla Owen, 1848
Suborder Ruminantia Scopoli, 1777
Superfamily Cervoidea Goldfuss, 1820

Fam., gen. et sp. indet.

(Fig. 3)

Material examined: MFM18126, right M_3.

Repository: Mizunami Fossil Museum, Mizunami, Japan.

Locality: 35° 26′ 07″ N and 137° 00′ 57″ E, the south riverside of the Kiso River, Dota, Kani City, Gifu Prefecture, central Japan (Fig. 1).

Horizon: The upperpart of the Nakamura Formation (lower Miocene: ca. 19 Ma), Mizunami Group (Fig. 2).

Measurements: Antero-posterior length = 18.6 mm; anterior labio-lingual width (maximum) = 9.3 mm; posterior labio-lingual width (maximum) = 8.8 mm; crown height at the protoconid = 7.6 mm (Fig. 3D).

Description: MFM18126 is the crown part of an isolated right M_3, without roots. The occlusal surface is less worn and forms the selenodont represented by the infraorder Pecora. The tooth size is comparatively small and as large as M_3 of extant chevrotains (Tragulidae) or musk deer (Moschidae). The mesostylid is very weak (or absent). The protoconid and metaconid are sharply pointed and have cristids surrounding the anterior fossa. The metastylid is prominent and is isolated from the metaconid by a small notch. The external postmetacristid is incomplete. The preprotocristid and the premetacristid are connected with one another at their anterior points, while the internal postprotocristid and the internal postmetacristid are separated. The external postprotocristid (*Palaeomeryx*-fold) is well-developed, extending from the protoconid to the base of the prehypocristid. There is a weak basal cingulid on the antero-labial side. The hypoconid and entoconid are very sharp. The prehypocristid approaches the posterior end of the internal postprotocristid, but these are separated each other by a deep gap. The anterior end of the preentocristid is connected (but is not fused) with the posterior end of the internal postprotocristid. The entostylid is prominent as well as the metastylid. The third lobe, including the back fossa, is composed of the hypoconulid with two stylids. The posthypoconulidcristid

extends to the entostylid, drawing an arc, because the entoconulid is almost absent. The prehypoconulidcristid does not connect with the posthypocristed. The ectostylids are very weak: the anterior one is probably broken and the posterior one is vestigial. The enamel surface is smooth without deep ditches.

Remarks: MFM18126 shows typical morphology of ruminant lower molars and is as large as those of small deer or antelopes. It has an external postprotocristid, which is a plesiomorphy of early ruminants (Janis and Scott, 1987; Gentry *et al*., 1999). MFM18126 is distinguished from M_3 of Tragulina (or Tragulidae and extinct chevrotains), which is characterized by more bunodont molars with the M-shaped structure composed of the external postprotocristid and the external postmetacristid. Therefore, the present specimen belongs to Pecora.

In Asia, Pecora is composed primarily of five families: i.e., Giraffidae, Palaeomerycidae, Cervidae, Moschidae, and Bovidae. Among these families, the external postprotocristid, characterizing MFM18126, is usually found in early species of Cervoidea (Cervidae + Moschidae). Palaeomerycid species also retain this characteristic and are generally included in Cervoidea (Janis and Scott, 1987), although they are considerably larger than the species of MFM18126.

Hassanin and Douzery (2003) suggested that Moschidae is placed in the sister clade of Bovidae and these families compose Bovoidea, based on both morphological and molecular data. Some recent paleontological studies supported that Moschidae has synapomorphies with Bovidae, such as a well-developed entoconulid and enclosing posterior cristids between the postentocristid and the posthypocristid (Sánchez *et al*., 2010; Wang *et al*., 2015). On the other hand, primitive species of Moschidae (*e.g*., *Dremotherium*) shares many dental characteristics with primitive species of Cevidae

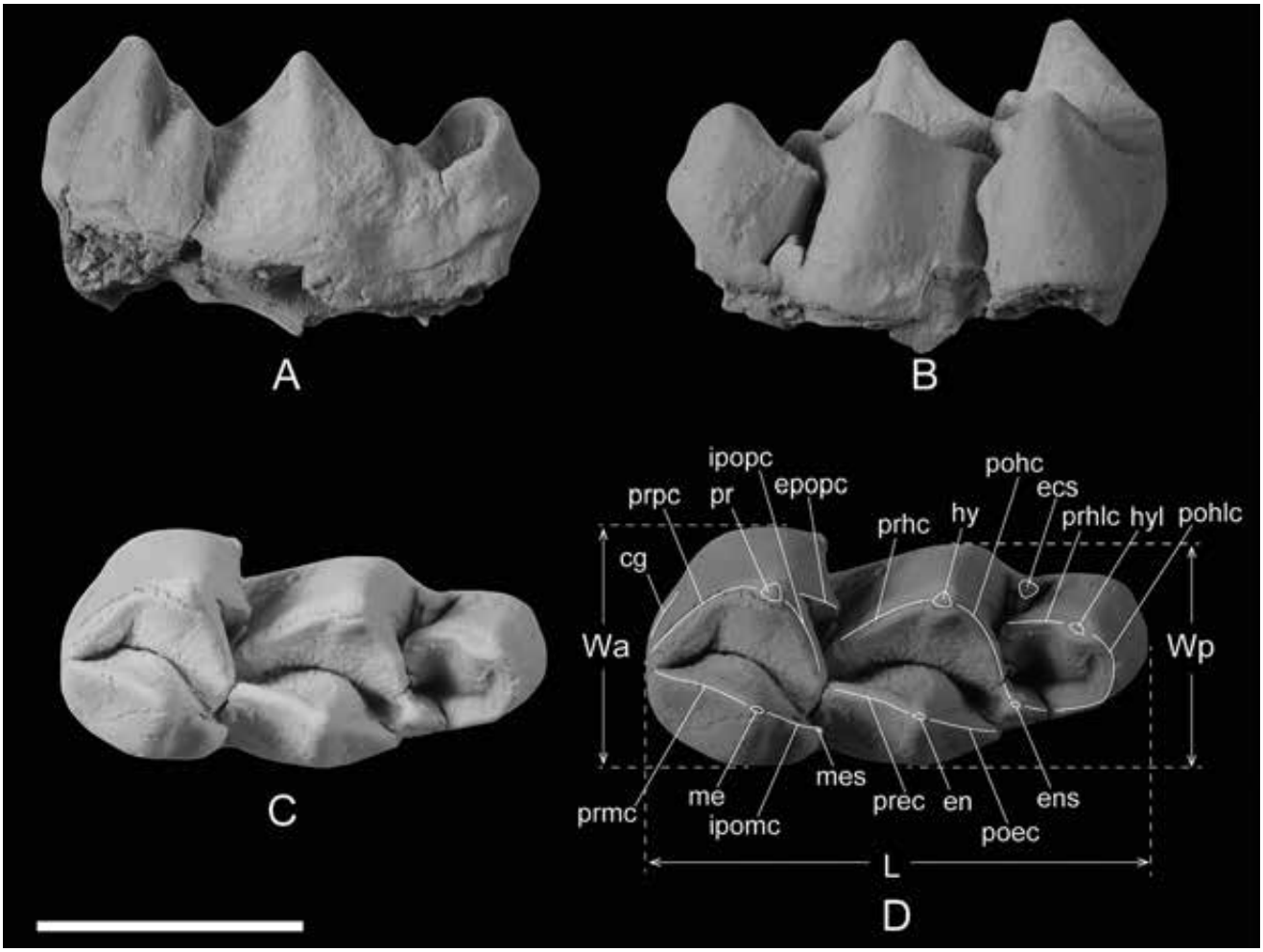


Fig. 3. Cervoidea fam., gen. et sp. indet. from the Miocene Nakamura Formation (Japan), MFM18126, right M_3. A, lingual view; B, labial view; C, occlusal view; D, dental terminology (after Bärmann and Rössner, 2011). Scale bar equals 10 mm. Abbreviations: cg, cingulid; ecs, ectostylid; en, entoconid; ens, entostylid; epopc, external postprotocristid; hy, hypoconid; hyl, hypoconulid; ipomc, internal postmetacristid; ipopc, internal postprotocristid; L, antero-posterior length; me, metaconid; mes, metastylid; poec, postentocristid; pohc, posthypocristid; pohlc, posthypoconulidcristid; pr, protoconid; prec, preentocristid; prhc, prehypocrisitd; prhlc, prehypoconulidcristid; prmc, premetacristid; prpc, preprotocristid; Wa, anterior labio-lingual width; Wp, posterior labio-lingual width.

(*e.g.*, *Procervulus*) or Palaeomerycidae (*e.g.*, *Amphitragulus*) (Janis and Scott, 1987; Gentry, 2000). The phylogenetic relationship of Moschidae is still debated, but MFM18126 at least lacks the synapomorphic characters of the [Bovidae + advanced species of Moschidae (*e.g.*, *Hispanomeryx* and *Micromeryx*] clade mentioned above.

MFM18126 is probably attributed to an early species of Cervidae or Moschidae, although it does not have any diagnosis either of the two family. Comparing with the Miocene cervids from Eurasia, the species of MFM18126 is similar to *Dicrocerus* or the other species of Lagomerycinae in size and shape (Ye, 1999; Rössner, 2010). *Dicrocerus grangeri* from the middle Miocene Halamagai Formation (ca. 17–15 Ma), Xinjiang Autonomous Region, China, corresponds to MFM18126 in having well-developed lingual stylids and no entoconulid (Ye, 1999).

MFM18126 is also similar to M_3 of a basal species of Moschidae, such as *Dremotherium* and *Pomelomeryx*. These late Oligocene and early Miocene moschids have been commonly found from Europe (Gentry *et al*., 1999; Rössner and Rummel, 2001; Prothero, 2007), and some species had been dispersed in East Asia (Vislobokova, 1997). Recently, Wang *et al*. (2015) described *Hispanomeryx* and *Micromeryx* from the middle Miocene of China, but these genera are more advanced than MFM18126, in having a strong entoconulid and enclosing posterior cristids.

The Mizunami Group yields several specimens of *Amphitragulus minoensis* Matsumoto, 1918, which currently belongs to Palaeomerycidae. The holotype (a right mandible with P_3 to M_2) of *A. minoensis* was collected from the Hiramaki Formation (ca. 18.4–17.0 Ma) of the Kani basin, and additional specimens have been collected from the Hachiya Formation (ca. 20.0 Ma) and Akeyo Formation (ca. 18.3–17.0 Ma) of the Kani and Mizunami basins, respectively (Kamei and Okazaki, 1974; Okazaki, 1977; Shikano and Ando, 2000).

The holotype of *A. minoensis* was originally stored at the Tono High School, Kani, Gifu Prefecture, Japan, but is currently lost. Moreover, no M_3 specimen of *A. minoensis* has been reported. Based on dental measurements described by Matsumoto (1918) and the plaster cast of the holotype (IGPS no. 22059, the Tohoku University Museum, Sendai, Japan), *A. minoensis* is clearly larger than the species of MFM18126 (Fig. 4). Moreover, M_2 of *A. minoensis* differs from MFM18126 (M_3) in having a flatter lingual wall and enclosing posterior cristids between the posthypocristid and the postentocristid.

Amphitragulus minoensis (or *Palaeomeryx minoensis* by Nagasawa, 1932) is similar to *Sinomeryx tricornis* (or *Palaeomeryx tricornis* Qiu *et al*., 1985) from the lower/middle Miocene of Shanwang (ca. 16–15 Ma), China. The lower molars of *S. tricornis* (V7730.1) are as large as the holotype of *A. minoensis*, and M_3 of *S. tricornis* is 1.6 times larger than MFM18126. According to Janis and Scott (1987), the genus *Amphitragulus* is usually has molars with a weak (or indistinct) external postprotocristid, a relatively broad crown, and an incomplete postentocristid compared to molars of Cervidae or Moschidae. In terms of these characteristics, MFM18126 is distinguished from *Amphitragulus* or its close relative genera of palaeomerycids.

There is a high probability that MFM18126 is the same species with *Dicrocerus tokunagai* Matsumoto in Tokunaga, 1927, which is known from the Misawa Formation (lower Miocene) and the lower part of the Asakawa Formation (lower middle Miocene), Fukushima Prefecture, northeastern Japan (Shikama and Ômori, 1952; Naora, 1997). The external postprotocristid of MFM18126 is stronger than that of *D. tokunagai*, although this structure usually changes due to wearing process in *Dicrocerus grangeri* from China.

In conclusion, the present fossil M_3 (MFM18126) is assignable to Cervoidea and differs from *Amphitragulus minoensis* (= *Palaeomeryx minoensis*) that was previously known from the Mizunami Group, indicating that two different cervoid ruminants had existed in the late early Miocene of central Japan. The species of MFM18126 is smaller than *A. minoensis* in size and is morphologically similar to *Dicrocerus tokunagai* from the lower and middle Miocene of eastern Japan and to *Dicrocerus* or Lagomerycinae cervids from

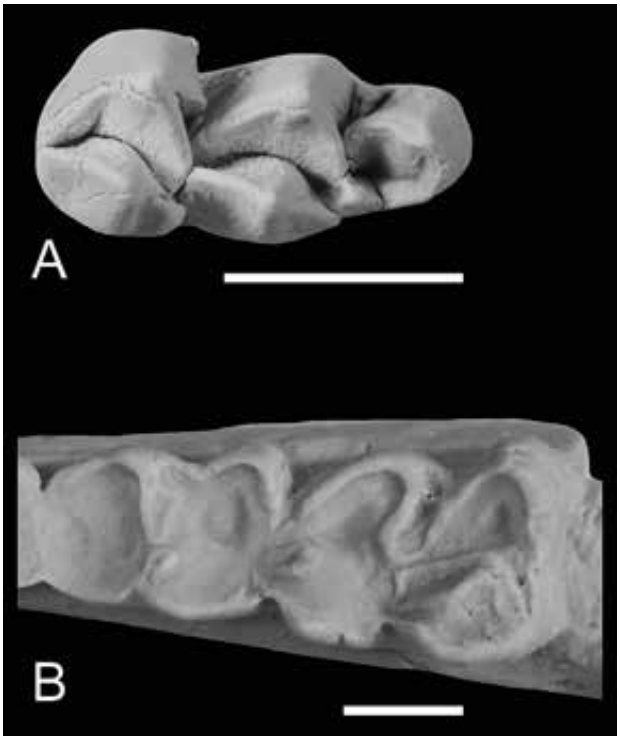


Fig. 4. Comparison of the lower molars (in occlusal view) of MFM18126 and *Amphitragulus minoensis*. A, MFM18126 (Cervoidea fam., gen. et sp. indet.), right M_3. B, *Amphitragulus minoensis* (IGPS no. 22059, right M_1 and M_2). Scale bars equal 10 mm.

contemporaneous China.

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