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Author: Naoto Handa
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Reassessment of a Pleistocene rhinocerotid (Mammalia, Perissodactyla) from Aira, Kagoshima, southwestern Japan

NAOTO HANDA

Museum of Osaka University, 1-20 Machikaneyama-cho, Toyonaka, Osaka 560-0043, Japan (e-mail: k1552325@kadai.jp)

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Abstract. This study describes the right upper postcanine teeth of a single individual of a Pleistocene rhinocerotid (Mammalia, Perissodactyla) from the lower to lower Middle Pleistocene Kamo Formation of the Kokubu Group in Aira City, Kagoshima Prefecture, southwestern Japan. These teeth are heavily worn and are identified as P2–M2 with missing M1. They are identified as an indeterminate genus and species of the Rhinocerotidae, although they were previously identified as *Rhinoceros* aff. *sinensis*. These dental fossil specimens and the rhinocerotid footprints from the lower to lower Middle Pleistocene of Japan indicate that rhinocerotids certainly existed in Japan during the early to early Middle Pleistocene.

Key words: Japan, Pleistocene, Quaternary, Rhinocerotidae, tooth

Introduction

The Pleistocene deposits of Japan yield many fossils of large terrestrial mammals. For example, abundant proboscidean fossils were discovered in the Pleistocene of Japan, and their paleobiogeography and migration timing between Japan and the Asian Continent have been discussed in several contributions (e.g. Kawamura, 1998; Konishi and Yoshikawa, 1999; Takahashi and Namatsu, 2000; Yoshikawa *et al*., 2007), although proboscideans do not now inhabit Japan. Similarly, although rhinocerotids do not now inhabit Japan, their fossils have been found in the Miocene to Pleistocene of Japan (Tomida *et al*., 2013; Nakagawa *et al*., 2013). The Pleistocene fossil records of the rhinocerotids in Japan are fewer than those of the proboscideans. Most rhinocerotid fossils from the Pleistocene in Japan are known from the middle Middle Pleistocene (*ca.* 0.5–0.4 Ma) (e.g. Handa and Pandolfi, 2016 and references therein). In contrast, early to early Middle Pleistocene rhinocerotid remains from Japan are scarce.

The Pleistocene rhinocerotid specimens from Japan have been previously considered to belong to *Dicerorhinus*, *Rhinoceros* or indeterminate genus (e.g. Shikama, 1967; Shikama *et al*., 1967; Kawamura *et al*., 1977; Taruno, 1988, 2000; Okazaki, 2007; Ogino *et al*., 2009). In the last decade, however, taxonomic revisions of the Pleistocene rhinoceroses of northern Eurasia and China have been conducted by many scholars (e.g. Groves, 1983; Fortelius *et al*., 1993; Cerdeño, 1995; Lacombat, 2005; Tong and Wu, 2010; Antoine, 2012; Tong, 2012; Yan *et al*., 2014; Pandolfi and Marra, 2015). Also, a few Japanese specimens have been taxonomically reappraised recently (Handa, 2015; Handa and Pandolfi, 2016; Handa and Takechi, 2017).

In the present work, I reappraise and describe upper postcanine teeth of a single rhinocerotid individual collected from the uppermost lower to lower Middle Pleistocene locality in Aira City, Kagoshima, Japan. This specimen were originally identified as *Rhinoceros* aff. *sinensis* based on a brief comparison with Chinese Pleistocene rhinocerotids by Shikama (1967). However, they have not been reappraised after the recent taxonomic revisions of the Pleistocene Eurasian taxa of the Rhinocerotidae.

Material and methods

The specimen described here were discovered in Aira City, Kagoshima Prefecture, southwestern Japan (Figure 1) and stored in Kagoshima Prefectural Museum, Kagoshima City. The taxonomy of the suprageneric classification of the family Rhinocerotidae used in this study follows Antoine *et al*. (2010). The dental terminology (Figure 2) follows Guérin (1980), Fukuchi (2003) and Antoine *et al*. (2010). Metrical methodology uses the standard measurement method by Guérin (1980).

In this study, the present specimen are compared with Pleistocene Asian taxa of the Rhinocerotidae, that is,

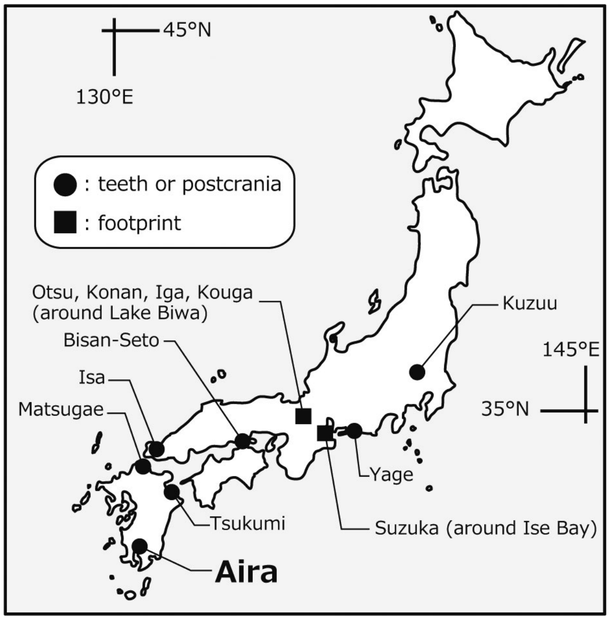

Figure 1. Map showing the localities of Pleistocene rhinocerotid fossil records in Japan (after Handa and Takechi, 2017). References: Shikama (1949) and Nagasawa (1961) for the Kuzuu locality, Tochigi Prefecture; Shikama (1967) and present study for the Aira locality, Kagoshima Prefecture; Shikama *et al*. (1967) and Handa and Pandolfi (2016) for the Isa locality, Yamaguchi Prefecture; Kawamura *et al*. (1977) for the Tsukumi locality, Oita Prefecture; Okazaki (2007) and Ogino *et al*. (2009) for the Matsugae locality, Fukuoka Prefecture; Handa (2015) for the Yage locality, Shizuoka Prefecture; Taruno (1988, 2000) and Handa and Takechi (2017) for the Bisan-Seto locality, Okayama Prefecture; Okamura *et al*. (2011, 2016) and Okamura (2016) for the Otsu, Koban, Iga, and Kousa localities (the Kobiwako Group) of central Japan and for the Suzuka locality (around Ise Bay) of Mie Prefecture.

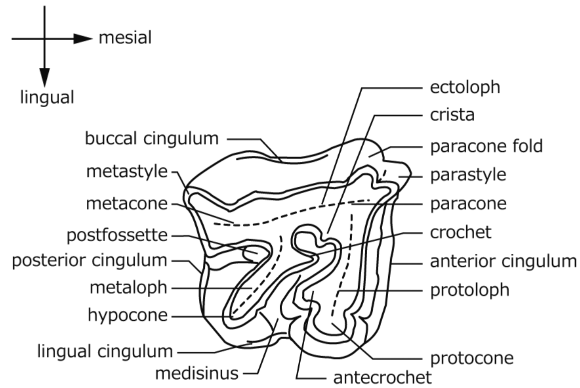

Figure 2. Terminology of the upper cheek tooth. Terminology follows Guérin (1980), Fukuchi (2003) and Antoine *et al.* (2010). Illustration is after Fukuchi (2003).

the subtribe Rhinocerotina (= the tribe Rhinocerotini in Heissig, 1973) and subtribe Elasmotheriina (= the tribe Elasmotheriini in Heissig, 1973) from Asia such as *Dicerorhinus*, *Rhinoceros*, *Dihoplus*, *Stephanorhinus*, *Coelodonta*, and *Elasmotherium*. Note that several extinct species of *Dicerorhinus* have been treated as *Stephanorhinus* or *Dihoplus* by several researchers (e.g. Tong and Wu, 2010; Tong, 2012; Handa and Pandolfi, 2016). This study follows those opinions.

The taxonomic status of *Rhinoceros* from Asia is still debatable. Two extinct species of *Rhinoceros* have been reported from Asia, namely *Rhinoceros sinensis* and *R. sivalensis*. Antoine (2012) noted that these extinct species should be treated as synonyms for *R. unicornis*. He also noted that other extinct species of *Rhinoceros* (*R. oweni*, *R. plicidens*, *R. simplicidens*, *R. chiai*, *R. palaeindicus*, *R. deccanensis*, *R. sinhaleyus*, *R. kagavena*) should be synonyms of for *R. unicornis*. Tong (2012) assigned several materials of *R. sinensis* to two species of *Stephanorhinus*. On the contrary, Yan *et al*. (2014) established *R. sinensis* and *R. sivalensis* as well as a new species of *Rhinoceros*, *R. fusuiensis*. Pandolfi and Maiorino (2016) also reported *R. sinensis* and *R. sivalensis* as valid species considering type and selected materials. Additionally, they redescribed a well preserved skull from the Upper Siwalik in India as *R. platyrhinus*. In this study, these species of *Rhinoceros* (*R. unicornis*, *R. sivalensis*, *R. sinensis*, *R. fusuiensis* and *R. platyrhinus*) are treated as distinctive taxa for comparison.

Institution abbreviations.—GMNH, Gunma Museum of Natural History, Gunma Prefecture, Japan; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Beijing, China; KPM, Kanagawa Prefectural Museum of Natural History, Odawara, Japan; NMMP, National Museum of Myanmar (Yangon, Myanmar), Paleontology; NMNS, National Museum of Nature and Science, Tsukuba, Japan.

Anatomical abbreviations.—P, upper premolar; M, upper molar.

Systematic paleontology

Family Rhinocerotidae Gray, 1821
Rhinocerotidae gen. et sp. indet.

Figure 3

Rhinoceros aff. *sinensis* Owen, 1870. Shikama, 1967, pl. 4 (1), figs. 1–4.

Material.—Specimen number F00000554, right P3−M2 (M1 is now missing), which belong to the same single individual. These teeth were originally described as right P2 to M1 by Shikama (1967). Generally, P2 of the rhinocerotids has a trapezoidal shape in occlusal view and

Table 1. P3 and P4 measurements of Rhinocerotidae gen. et sp. indet. (F00000554) from the Pleistocene Kamo Formation of Japan and the compared specimens (in mm). Abbreviations: *L*, length; *W*, width; *H*, height.

	P3			P4				
Taxa	*L*	*W*	*H*	*L*	*W*	*H*	Reference	Remarks
Rhinocerotidae gen. et sp. indet.	30.12	>43.65	18.90	32.69	>51.80	15.26	present study	F00000554
Rhinoceros fusuiensis	34.20−38.80	43.90−50.00	–	34.80−43.90	45.30−53.80	–	Yan *et al*. (2014)	Yanliang Cave (China) materials
Rhinoceros sinensis	32.00−42.00	51.00−63.00	–	35.00−48.00	57.00−70.00	–	Yan *et al*. (2014)	Yanjinggou (China) materials
Rhinoceros sinensis	31.30−37.80	46.00−55.50	–	34.00−47.00	49.90−60.00	–	Yan *et al*. (2014)	Longgudong (China) materials
Rhinoceros sivalensis	40.60	58.40	–	38.10	66.00	–	Zin-Maung-Maung-Thein *et al*. (2010)	
Rhinoceros unicornis	42.40	60.85	46.73	43.35	65.79	52.22	direct observation	KPM-NF1002747 (extant)
Rhinoceros unicornis	42.86	57.85	45.08	45.15	67.19	53.72	direct observation	KPM-NF1002747 (extant)
Rhinoceros unicornis	43.00−50.00	55.50−60.50	–	42.00−51.00	59.00−69.50	–	Yan *et al*. (2014)	
Rhinoceros sondaicus	36.50–50.00	42.00–55.00	–	41.00–47.50	52.00–59.00	–	Yan *et al*. (2014)	
Rhinoceros sondaicus	34.00	35.70	–	37.10	44.00	–	Zin-Maung-Maung-Thein *et al*. (2010)	DG-MC 0001
Rhinoceros sondaicus	47.00	57.00	–	42.00	62.00	–	Zin-Maung-Maung-Thein *et al*. (2010)	Dub. 1983
Rhinoceros platyrhinus	69.79	78.47	–	72.47	95.49	–	Pandolfi and Mariorino (2016)	estimated based on Figure 4F in Pandolfi and Mariorino (2016)
Dicerorhinus gwebinensis	34.00	48.00	–	41.00	49.00	–	Zin-Maung-Maung-Thein *et al*. (2008)	NMMP-KU-IR 0469-1
Dicerorhinus sumatrensis	35.68	44.43	>14.08	38.47	50.83	12.36	Tong and Guerin (2009)	IVPP-V2877
Dicerorhinus sumatrensis	33.50−37.50	37.00−47.00	–	36.00−39.00	42.50−51.50	–	Yan *et al*. (2014)	
Dicerorhinus sumatrensis	29.00	38.60	26.90	32.40	45.30	33.20	direct observation	GMNH-VM-562 (extant, cast)
Dicerorhinus sumatrensis	28.70	39.10	27.70	29.50	45.00	34.20	direct observation	GMNH-VM-562 (extant, cast)
Stephanorhinus kirchbergensis	39.70	53.40	44.20	42.90	56.10	38.30	Handa and Pandolfi (2016)	NMNS-PV9600: Japanese material
Stephanorhinus kirchbergensis	45.60−51.80	60.60−61.30	–	54.70	63.70	–	Handa and Pandolfi (2016)	Migong Cave (China) materials
Stephanorhinus kirchbergensis	–	–	–	48.30	67.10	–	Handa and Pandolfi (2016)	Rhino Cave (China) material
Stephanorhinus kirchbergensis	38.20−43.20	55.90−60.20	–	44.20−51.00	60.80−66.30	–	Handa and Pandolfi (2016)	Anping (China) materials
Stephanorhinus kirchbergensis	38.00−39.00	57.00−61.00	–	44.00−50.00	64.00−69.00	–	Handa and Pandolfi (2016)	Choukoutien (China) materials
Stephanorhinus yunchuchenensis	37.00	–	–	42.00	58.00	–	Handa and Pandolfi (2016)	Yushe (China) material
Coelodonta nihowanensis	40.50	50.00	39.00	42.00	55.50	46.50	Deng (2002)	Linxia basin (China) material
Coelodonta antiquitatis	33.00−43.00	35.00−47.50	44.00−68.00	37.00−51.50	44.00−55.50	53.50−69.00	Guérin (1980)	
Dihoplus ringstroemi	44.00	69.00	–	50.00	69.00	–	Deng (2006)	estimated based on Figure 3 in Deng (2006)
Elasmotherium peii				47.00	57.00	–	Tong *et al*. (2014)	
Elasmotherium caucasicum	45.00−46.00	45.00−47.00	–	40.00−62.00	50.00−57.00	–	Tong *et al*. (2014)	
Elasmotherium sibiricum				41.00−49.50	39.80−50.00		Tong *et al*. (2014)	

is smaller than that of P3 (Guérin, 1980). However, "P2" described by Shikama (1967) has a relatively rectangular outline (Figure 3) and its size is similar to that of the "P3" described by Shikama (1967) (Table 1). Therefore, the tooth formula of "P2 to M1" described by Shikama (1967) is revised to P3 to M2 in this study. Originally, M1 ("P4" in Shikama, 1967) was collected together with other teeth at that time, but it is currently lost.

Dental measurements.—Shown in Table 1.

Locality and horizon.—Around Nishihinabe area in

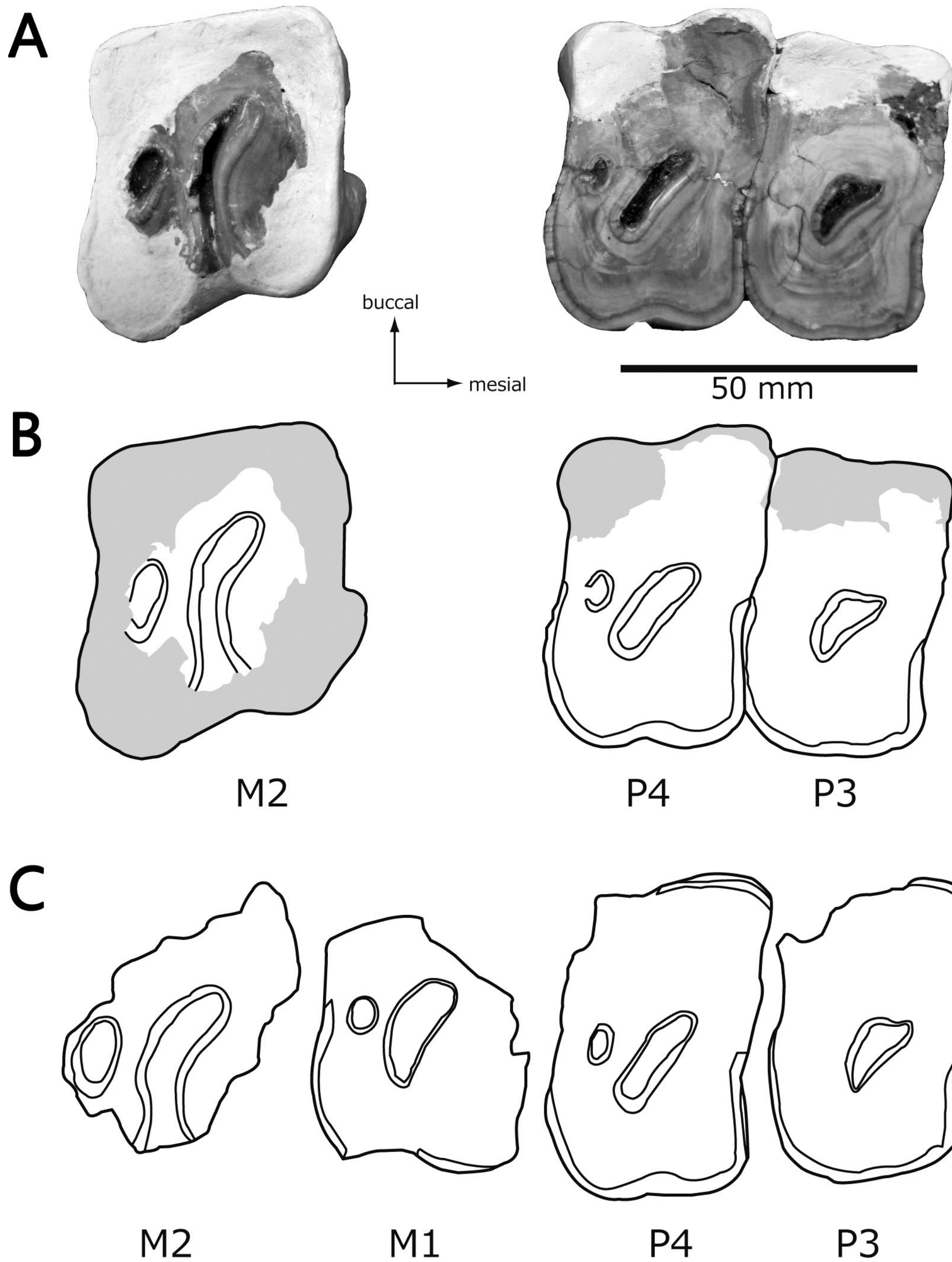

Figure 3. Rhinocerotidae gen. et sp. indet. (F00000554) from the Pleistocene Kamo Formation of Japan. **A,** occlusal view; **B,** schematic drawing; **C,** schematic redrawing based on the figure of Shikama (1967).

Kajiki town, Aira City, Kagoshima Prefecture, southwestern Japan (Figure 1); the Kamo Formation of the Kokubu Group (Figure 5); possibly latest early to early Middle Pleistocene (> 0.5 Ma), as explained below.

According to Shikama (1967), the present teeth (F00000554) were collected from the lower Pleistocene "Yoshida clay bed" in Aira City. Later, Otsuka and Nishiinoue (1980) reinvestigated in detail the fossil locality based on the lithology of the matrix of the studied specimen and the fossil pollen assemblage in the matrix, suggesting that the specimen was derived from the Kamo Formation of the Kokubu Group around Nishihinabe area in Kajiki town, Aira City.

The Kokubu Group is the lower to Middle Pleisto-

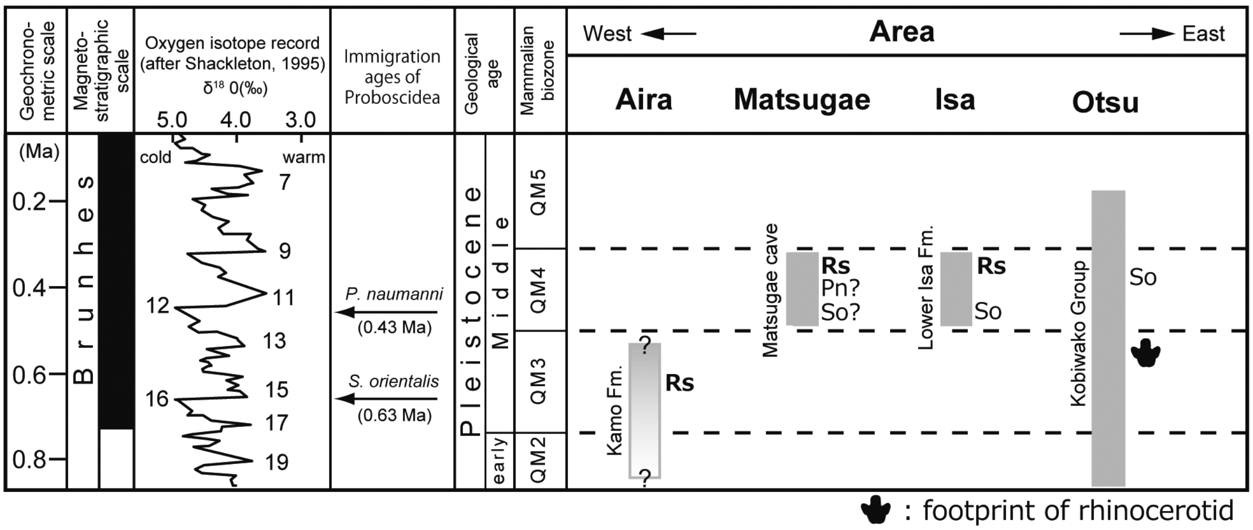

Figure 4. Chronology and stratigraphy of selected Japanese Pleistocene rhinocerotid fossils, and immigration events of the Proboscidea in Japan (after Ogino *et al*., 2009; Okamura *et al*., 2011). Abbreviations: Pn, *Palaeoloxodon naumanni*; So, *Stegodon orientalis*; Rs, rhinocerotid; Fm., formation; QM, Quaternary Mammal zones of Japanese Islands (Kamei *et al*., 1988). The numbers in the oxygen isotope record indicate Marine isotope stages (MIS).

cene deposits (*ca.* 1 Ma to 0.5 Ma) which is distributed in the northern part of Kagoshima Prefecture (Uchimura *et al*., 2014). The Kokubu Group is subdivided into the Kajiki, Nabekura, Kamo, Obama, Asahi, Oda, Hayato, and Fumoto formations in ascending order (Kagawa and Otsuka, 2000). Whole-rock K–Ar dating provided ages of 0.87 ± 0.50 Ma for the Yuwandake andesite which intrudes into the Nabekura Formation (Kagawa and Otsuka, 2000; Uchimura *et al*., 2014). The age of the Kobayashi pyroclastic flow deposits overlying the Kokubu Group is estimated to be *ca.* 0.52 Ma (Uchimura *et al*., 2014). The Kuwanomaru pyroclastic flow deposit in the Kamo Formation is correlated with the Shimokado pyroclastic flow deposits (0.57 ± 0.03 Ma) in the northwestern part of Kagoshima Prefecture (Uchimura *et al*., 2014 and reference therein). In conclusion, the age of the Kamo Formation is probably the latest early to early Middle Pleistocene (> 0.5 Ma).

Description.—The teeth are heavily worn down and their occlusal surfaces are almost flat in mesio-distal view. M2 is almost broken except around the medisinus. In all the teeth the medisinus is deeper than the postfossette. The teeth all have no dental cement. M1 is lost as mentioned above, thus the morphological characteristics of M1 are based on the description and figures by Shikama (1967) (Figure 3C).

P3 is relatively well preserved but heavily worn. It is wider than long. The marginal profile of the ectoloph is unclear because this portion is covered with plaster. Based on the figure of Shikama (1967), no trace of the paracone fold and the parastyle can be observed (Figure 3C). The protoloph and metaloph are connected to each other at this stage of wear. Thus, the medisinus is closed and is subtriangular in occlusal view. The postfossette is not preserved at this wear stage. The presence of the crochet and crista is uncertain. There are no buccal and lingual cingula. The trace of the anterior cingulum is located on the mesio-lingual corner of the protocone. The posterior cingulum is not preserved. The preserved enamel surface is smooth.

P4 is relatively well preserved as in P3. The buccal and disto-buccal corners are covered with plaster. At the stage of wear, the morphology of the tooth is similar to that of P3, namely, a connection of the protoloph with the metaloph, absence of the cingula, a closed mediofossette, and a smooth enamel surface. The mediofossette is narrow. The posterior fossette is oval. The presence of the paracone fold and parastyle cannot be observed due to the heavy wear.

Based on the description and figures by Shikama (1967), the buccal side of M1 (“P4” in Shikama, 1967) is broken (Figure 3C). The mediofossette is narrow and oval-shaped and is relatively larger than that of P4. A small postfossette is preserved. It is uncertain whether the lingual cingulum is present or not.

M2 consists only of a small portion of the tooth. The middle part of the tooth is covered by plaster. The medisinus is narrow and mesially curved. The protoloph and metaloph are not connected with each other. Secondary folds such as crochet, antecrochet, and crista are not vis-

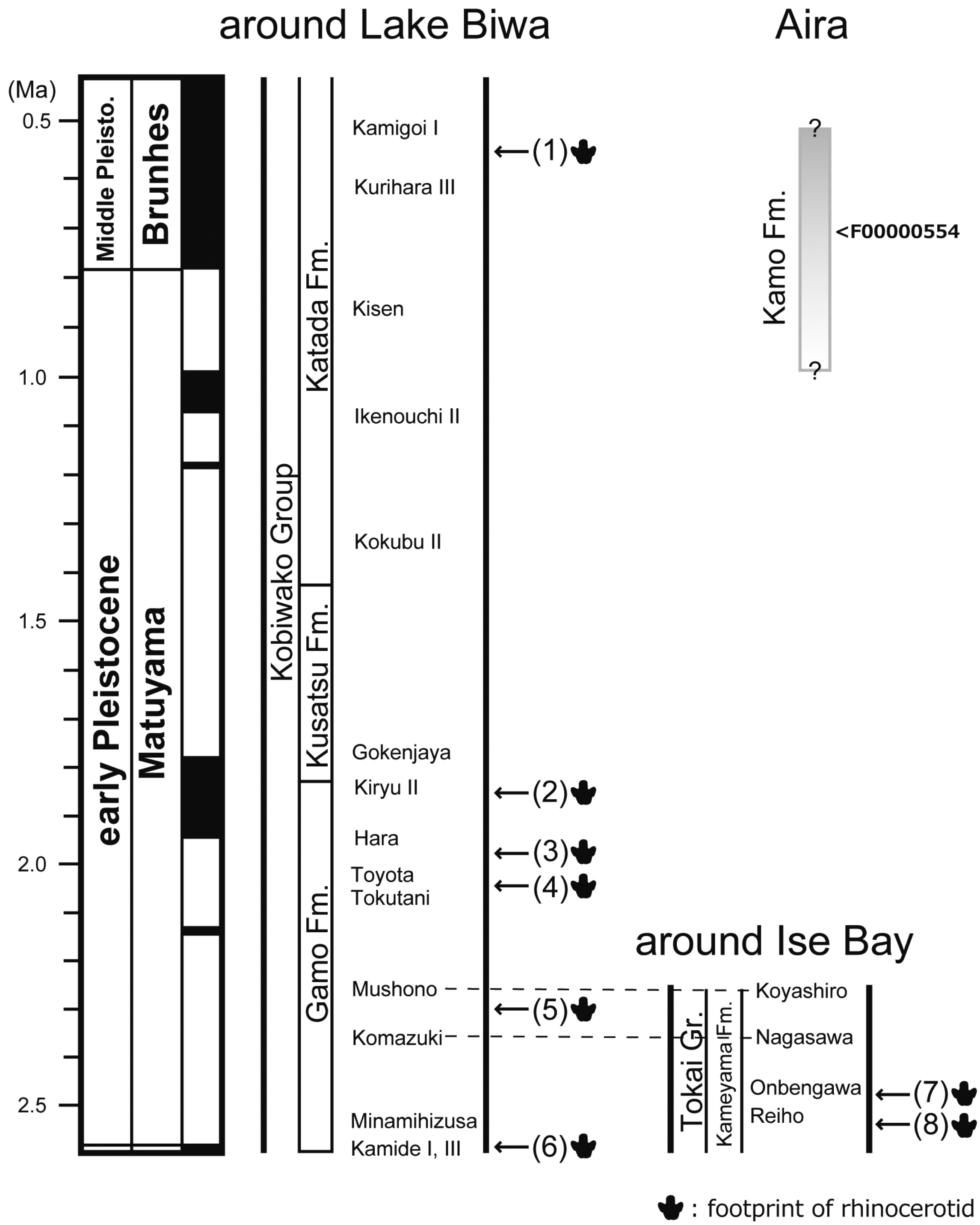

Figure 5. Stratigraphic distribution of major rhinocerotid footprint fossils from the Pleistocene around Lake Biwa and Ise Bay of central Japan, and the stratigraphic range and rhinocerotid horizon of the Aira Formation of Kagoshima Prefecture. The tephro- and magnetostratigraphy are after Satoguchi (2017). The localities of footprint fossils (Okamura *et al*., 2011, 2016; Okamura, 2016) are as follows: (1) Ikadachimukouzaichi Town, Otsu City, Shiga Prefecture; (2) Yamakami Town, Higashioumi City, Shiga Prefecture; (3) Mashita, Hino Town, Gamou District, Shiga Prefecture; (4) Nakayama, Hino Town, Gamou District, Shiga Prefecture; (5) Mizuguchi Town, Kouga City, Shiga Prefecture; (6) Yoshinaga, Konan City, Shiga Prefecture; (7) Ifuna Town, Suzuka City, Mie Prefecture; (8) Higashishounai Town, Suzuka City, Mie Prefecture.

ible at this stage of wear. The oval-shaped postfossette is preserved and located posterior to the medisinus.

Comparisons

The present specimen are lophodont cheek teeth which consist of the protoloph, metaloph, and ectoloph. These morphologies are typical characteristics of the rhinocerotids (Heissig, 1999). In Eurasia, five tribes of the Rhinocerotidae (Aceratheriini, Teleoceratini, Elasmotheriini, Rhinocerotini, and Dicerotini: *sensu* Heissig, 1973) were distributed during the Miocene to early Pliocene. After the late Pliocene, however, only two subtribes of the Rhinocerotini survived in Eurasia (e.g. Heissig, 1989), namely Rhinocerotina (*Rhinoceros*, *Dicerorhinus*, *Stephanorhinus*, *Dihoplus*, and *Coelodonta*) and Elasmotheriina (*Elasmotherium*) (e.g. Guérin, 1980; Lacombat, 2005; Zin-Maung-Maung-Thein *et al*., 2008, 2010; Tong and Moigne, 2000; Tong, 2012; Yan *et al*., 2014; Pandolfi and Maiorino, 2016).

The specimen described here is distinguished from *Coelodonta* and *Elasmotherium*. The upper cheek teeth of *Coelodonta* have the followin dental features, which the present specimen lacks: a rugose enamel surface, upper molars longer than wide, and distally elongated proto- and metalophs (Qiu *et al*., 2004; Tong and Wang, 2014). The upper cheek teeth of *Elasmotherium* also differ from the present specimen in having a corrugated enamel layer (e.g. Antoine, 2002; Schvyreva, 2015).

The development of the secondary fold (including crochet, crista and antecrochet) and the ectoloph profile in the Rhinocerotidae are often used for taxonomic identification in the family (Guérin, 1980; Zin-Maung-Maung-Thein *et al*., 2010; Yan *et al*., 2014; Handa and Pandolfi, 2016). Shikama (1967) noted that several molars of *Rhinoceros sinensis* described by Colbert and Hooijer (1953) have an obsolete crochet and that this character is similar to the Aira specimen. However, the present specimen are heavily worn, so the development of the secondary fold of the present specimen cannot be evaluated for comparison.

Shikama (1967) noted that the "P3" (= P4 in the present study) length is similar in size to that of *Rhinoceros sinensis* from the "*Stegodon* bed" of Szechwan, China (P3 length is 32–42 mm: Colbert and Hooijer, 1953). Compared with the several species of the Rhinocerotidae from Asia, the P3 and P4 dimensions of the present specimen are much smaller than those of *Stephanorhinus* and *Dihoplus* from Asia (Table 1). *Rhinoceros platyrhinus* from the Upper Siwalik of India is also distinguished from the present specimen in having larger dental dimensions (Table 1). The dimensions of the present specimen resemble the minimum size of the range of teeth of *R. sinensis* from Longgudong in China, and the teeth of *D. sumatrensis* of the GMNH-VM-562 (living individual, cast specimen) (Table 1). Based on the dental size similarity, therefore, the present specimen is comparable to *R. sinensis* or *D. sumatrensis*. However, the dental features that can be observed in the present specimen do not permit any tribal diagnosis. Additionally, the present specimen is heavily worn, so that the dental size can be also influenced by the wear. Therefore, a tribal or more precise taxonomic identification of the present specimen is impossible.

Discussion

Among the Plio-Pleistocene rhinocerotid fossils recovered from Japan, most have been from the middle Middle Pleistocene (*ca.* 0.5–0.4 Ma) (e.g. Handa and Pandolfi, 2016 and references therein). The Japanese rhinocerotid records in the Pliocene and lower to lower Middle Pleistocene are scarce.

Only three rhinocerotid fossil occurrences have so far been recorded in Japan, and all of them are from mid-Pliocene (around 3.6 to 3.5 Ma) localities (e.g. Nakagawa *et al*., 2013). An unciform was found from the Kanzawa Formation in Kanagawa Prefecture (Hasegawa *et al*., 1991). Isolated lower cheek teeth were described from the Tsubusagawa Formation in Oita Prefecture (Kato, 2001). Finally, a lunar was reported from the Ueno Formation of the Kobiwako Group in Mie Prefecture (Yamamoto, 2006).

Although there is no other dental or skeletal fossil (body fossil) material from the lower Pleistocene in Japan so far except for the present dental specimen (from the lower or lower Middle Pleistocene), a number of rhinocerotid footprints (trace fossils) have been documented from the lower Pleistocene of Japan (Okamura *et al*., 2011, 2016; Okamura, 2016; Figure 5). The Gamo and Kusatsu formations of the Kobiwako Group around Lake Biwa, central Japan have yielded chronologically continuous rhinocerotid footprints (Okamura *et al*., 2011, 2016; Okamura, 2016). Several rhinocerotid footprints are also known from the Kameyama Formation of the Tokai Group in Suzuka City, Mie Prefecture, central Japan (Okamura, 2016 and references therein). Additionally, a rhinocerotid footprint is also known from the upper Pliocene to lower Pleistocene Gunchu Formation (Ikeda *et al*., 2017) in Iyo City, Ehime Prefecture, although the details of the footprint-bearing horizon are uncertain (Okamura, 2016).

The age of the present specimen is the early Pleistocene to early Middle Pleistocene, so that the present specimen fill the gap of the Japanese records of rhinocerotid dental/skeletal fossils between the mid-Pliocene and the middle Middle Pleistocene (Figure 4). Furthermore, rhinocerotid footprints were discovered in the early Middle

Pleistocene (*ca*. 0.55 Ma) of the Katada Formation of the Kobiwako Group in Otsu City, Shiga Prefecture, central Japan by Okamura (2011) (Figures 1, 4). The presence of the present dental specimens in Aira with the presence of rhinocerotid footprints in the lower to lower Middle Pleistocene in Japan indicates that the rhinocerotids certainly existed in central/western Japan through the mid-Pliocene to Middle Pleistocene (Figures 1, 4, 5).

Several taxa of the Pleistocene terrestrial mammalian fauna in Japan are considered to have migrated from the Asian Continent into Japan through land bridges between them. The times of two migrations of terrestrial mammal fauna into Japan have been estimated based on the fossil occurrences of the two proboscidean species common to Japan and China (Kawamura, 1998; Konishi and Yoshikawa, 1999; Yoshikawa *et al*., 2007). The timing of the first migration is around 0.63 Ma (Marine isotope stage [MIS] 16), with *Stegodon orientalis* and several other taxa of the southern Chinese fauna. The timing of the second migration is around 0.43 Ma (MIS 12), with *Palaeoloxodon naumanni* and some other taxa of the northern Chinese fauna (Figure 4). Handa and Pandolfi (2016) have noted that *Stephanorhinus kirchbergensis* from the Middle Pleistocene in Isa, Yamaguchi Prefecture, western Japan (Figure 1), likely migrated during the second migration based on the composition of the Isa mammal fauna. Furthermore, the Matsugae mammalian fauna (including the Rhinocerotidae) from Matsugae in Fukuoka Prefecture, western Japan (Figure 1), was correlated with Quaternary Mammal Zone 4 (QM4: middle Middle Pleistocene) of the Japanese Islands (Figure 4; Kamei *et al*., 1988), and was also considered to be of the time of the second migration based on similarity with the Northern Chinese Locality 1 of the Choukoutien fauna (Ogino *et al*., 2009) (Figure 4). However, the relationship between the first migration event (*ca.* 0.63 Ma) and the Japanese Pliocene to early Middle Pleistocene rhinocerotids is still unclear due to the scarcity of the fossil records.

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