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A rhinocerotid (Mammalia, Perissodactyla) from the late Miocene Oiso Formation, Kanagawa Prefecture, Japan

ZIN-MAUNG-MAUNG-THEIN[1], HAJIME TARU[2], MASANARU TAKAI[1] AND AKIRA FUKUCHI[3]

[1]*Primate Research Institute, Kyoto University, Inuyama, Aichi 484-8506, Japan (email: zinmaung@pri.kyoto-u.ac.jp; takai@pri.kyoto-u.ac.jp)*
[2]*Kanagawa Prefectural Museum of Natural History, Kanagawa 250-0031, Japan (email: taru@nh.kanagawa-museum.jp)*
[3]*Hanshin Consultants Co., Ltd., Satsumasendai, Kagoshima 895-0132, Japan (email: afkc@po5.synapse.ne.jp)*

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Introduction

We describe a fragmentary tooth of a rhinocerotid perissodactyl recovered from the middle unit of the upper Miocene Oiso Formation, Japan. Although the specimen is fragmentary and heavily worn, it is worth describing because the fossil record of the Miocene rhinoceroses in Japan is little known. Taxonomy used in this paper follows Antoine *et al*. (2003) and dental terminology follows the convention by Guérin (1980).

The Oiso Formation is distributed at the southeastern side of Oiso Hill, Kanagawa Prefecture, eastern Japan (Figure 1). It is mainly composed of pebbly sandstones with tuff in the lower unit, turbidites with some conglomerate layers in the middle unit, and mudstones with tuff in the upper unit (Ito, 1986). The rhinocerotid teeth described here was recovered from the conglomerate layers in the middle unit, which also yields mollusks (Taguchi and Matsushima, 1997), marine vertebrates (sharks, rays and whales) (Yabe and Hirayama, 1998; Tanaka and Mori, 1996) and a molar fragment of a suid (*Hippopotamodon* or *Propotamochoerus*) (Oshima, 2007). The geological age of the Oiso Formation has been estimated to be late Tortonian to early Messinian on the basis of planktonic foraminifera (ca. 8.6–6.6 Ma (N17); Ibaraki, 1978) and calcareous nannofossils (ca. 8.3–5.7 Ma (CN9); Kanie *et al.*, 1999) (Gradstein *et al.* 2005).

Systematic Palaeontology

Family Rhinocerotidae Owen, 1845
Subfamily Rhinocerotinae Dollo, 1885
Tribe Rhinocerotini Gray, 1821
Subtribe Teleoceratina Hay, 1902

Genus ***Brachypotherium*** Roger, 1904
***Brachypotherium* sp.**

Figure 2

Material.— KPM-NNV 50, fragments of a right upper molar (M^1 or M^2) including a lingual portion of protoloph, a median valley and a fragment of ectoloph.

Locality.—Nishikoiso coast, Oiso Town, Kanagawa Prefecture, Japan (Figure 1)

Repository.—Kanagawa Prefectural Museum of Natural History (KPM), Odawara, Japan.

Formation and age.—Middle unit of the Oiso Formation; Late Miocene (N17 and CN9; 8.3–5.7 Ma: Ibaraki, 1978; Kanie *et al.*, 1999) (Gradstein *et al.*, 2005).

Description.—The specimen consists of three fragments of a single upper postcanine tooth: a lingual portion of the protoloph, a part of the median valley and a fragment of the ectoloph. We locate each part in the appropriate place and draw a reconstructive configuration (Figure 2). The estimated tooth dimension is 70 mm in length and 65 mm in width. It shows brachyodonty and wears down nearly to the level of the anterior cingulum, indicating that it is an adult individual. At this wear stage, the height of the lingual portion of the protoloph is 22 mm. Of the ectoloph only the mesiobuccal portion is preserved, showing a weak parastyle fold, although the parastyle is broken. The enamel is thick at the lingual wall of the protoloph (∼3.0 mm) and is thin at the crochet (∼1.2 mm). The protocone is slightly constricted. The median wall of the protoloph is broken but the distally curving enamel pattern indicates the presence of the antecrochet. The medifossette is absent. The median valley is filled up with cement and is open lingually. The crochet is well developed and directs buccally. The blunt crista is developed. Two small cristellas are also present. The anterior cingulum

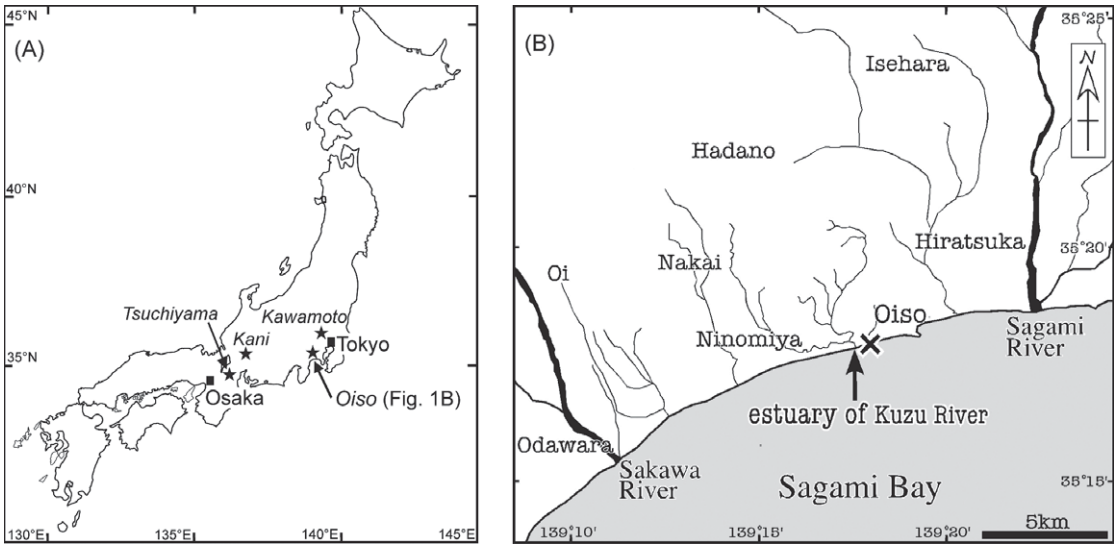

Figure 1. **A**, Map showing the Miocene rhinoceros fossil localities in Japan: Tsuchiyama (Rhinocerotidae gen. et sp. indet.: early middle Miocene, Ayugawa Group); Kani (*Chilotherium pugnator*: middle Miocene, Kani Group); Kawamoto (Teleoceratinae gen. et sp. indet.: late Miocene, Yagii Formation); and Oiso (*Brachypotherium* sp.: late Miocene, Oiso Formation). **B**, Map showing the locality (X) of the present specimen (*Brachypotherium* sp.) at Oiso.

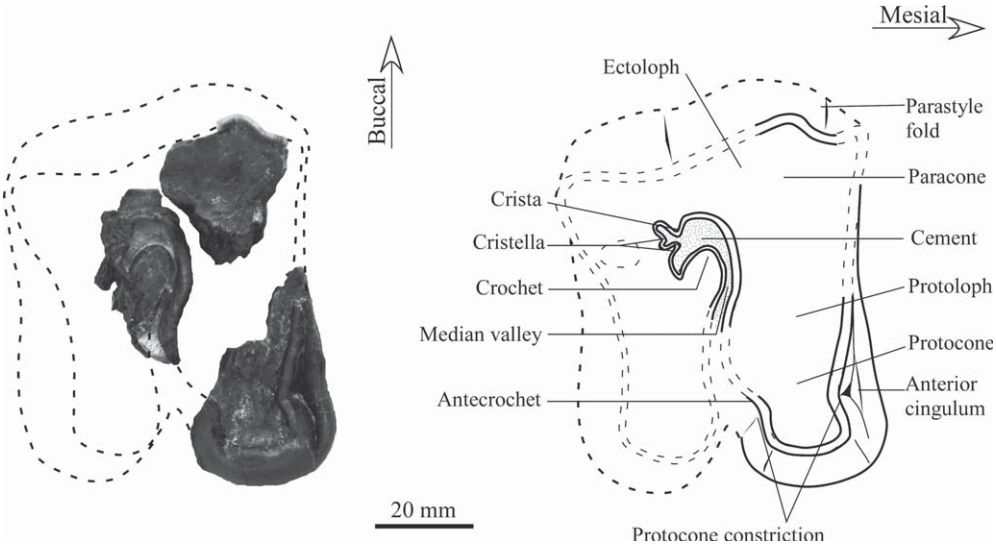

Figure 2. Right M^1 or M^2 of *Brachypotherium* sp. from the late Miocene Oiso Formation, Kanagawa Prefecture, Japan. Photos of three fragments of a single molar (left) and a line drawing of the reconstructed tooth (right). Dashed line indicates the reconstructed shape.

is restricted to the mesial tooth edge. The absence of the lingual cingulum can not be determined with confidence although it is absent at the level of the protocone.

Comparison and discussion.—Although fragmentary, KPM-NNV 50 can be recognized as a molar of a large rhinocerotid (M^1 or M^2) based on the following dental characteristics: the tooth shows lophodonty; a median valley is filled up with cement; the development of antecrochet, crochet, crista and cristella; a fragment of ectoloph with parastyle fold (e.g. Prothero, 1986; Heissig, 1989). Due to the poor preservation and advanced wear stage of the present specimen, a limited number of characteristics are available for taxonomic comparison. Nevertheless, KPM-NNV 50 is characterized by its large tooth size, the slightly constricted protocone, the presence of antecrochet, the well developed crochet, and the absence of cingulum at the lingual protoloph. These characteristics closely match the M^1 or M^2 of the teleoceratine rhinoceros, *Brachypotherium*

documented from the Miocene of Eurasia and Africa (Heissig, 1972; Hooijer, 1978; Guérin, 1980). Our specimen is similar to *Brachypotherium brachypus* and *Brachypotherium goldfussi* from the middle to late Miocene of Europe in having a weak protocone constriction, antecrochet and well developed crochet but differs from them in the presence of a distinct crista and cristella (Guérin, 1980). It shows similar characteristics to *Brachypotherium perimense* from the middle to late Miocene of the Indian Subcontinent and Myanmar in having a weakly constricted protocone, distinct crochet, crista and rudimentary cristella (Colbert, 1935; Heissig, 1972). However, these dental characteristics, such as a strongly constricted protocone, a large antecrochet, a cingulum and a crista, have appeared independently several times in different rhinocerotid groups, providing no reliable taxonomic assignment for most isolated teeth at the generic/species level (Forster-Cooper, 1934; Prothero, 2005). Nevertheless, the preserved dental characteristics and the large tooth size indicate that this specimen is closely related to *Brachypotherium*. Therefore, we refer herein KPM-NNV 50 to *Brachypotherium* species indeterminate.

KPM-NNV 50 is distinct from other teleoceratine rhinoceroses. It is distinguished from *Teleoceras* of the Miocene of North America, whose teeth are characterized by hypsodonty and in which the protocone on the molars is relatively strongly constricted (Prothero, 1986, 2005; Cerdeño, 1995). It is also different from *Aprotodon* of South Asia in the presence of the weakly constricted protocone and stronger crochet (Colbert, 1935; Heissig, 1972; Antoine *et al.*, 2003).

KPM-NNV 50 is distinguished from other rhinocerotid groups. Its features deny a close affinity with the rhinocerotines, showing the protocone constriction and antecrochet (Cerdeño, 1995; Antoine, 2002, 2003; Antoine *et al.*, 2003). It is also distinguished from the elasmotheres in the absence of corrugated enamel and a strong protocone constriction (Cerdeño, 1995; Antoine, 2002, 2003; Antoine *et al.*, 2003). It does not show a close affinity with the aceratheriine rhinoceroses from Europe, East and South Asia. It differs from *Aceratherium* of the late Miocene of Europe in being larger and in having a stronger crochet and crista/cristella (Guérin, 1980; Antoine *et al.*, 2003). It is also distinguished from *Acerorhinus* of the middle to late Miocene of China in that the tooth dimension is small, the protocone is more strongly constricted, the crochet is comparatively weak, and the crista and cristella are generally absent on the molars (Cerdeño, 1995, 1996). It differs from *Alicornops* from the late Miocene of Europe and China in being larger and in having a less pronounced protocone constriction and weaker crochet (Cerdeño and Snchez, 2000; Deng, 2004). It is distinguished from *Chilotherium* of the late Miocene of Asia in the absence of a strongly constricted protocone and in having a larger tooth size (Deng, 2006; Antoine *et al.*, 2003). It is also distinct from *Subchilotherium* of South and East Asia, in which the crochet is less developed and the posterior groove of the protocone is absent (Colbert, 1935; Heissig, 1972; Qiu and Dong, 2006).

Brachypotherium was widely distributed in MN 6 to MN 9 of Europe and the eastern Mediterranean region (Heissig, 1996, 1999), in the middle to late Miocene of Africa (Hooijer, 1978), in the early to the late Miocene Bugti and Siwalik Hills of the Indian Subcontinent (Heissig, 1972; Métais *et al.*, 2009) and in the Miocene of Myanmar (lower part of the Irrawaddy Sediments) (Chavasseau *et al.*, 2006). The present discovery suggests the extensive distribution of this clade in the late Miocene of Far East Asia. In the Miocene of Japan, the following rhinoceroses have been recorded besides the present discovery (Figure 1A): an indeterminate rhinocerotid from the lower middle Miocene Ayugawa Group (Kimura *et al.*, 1994); *Chilotherium pugnator* from the middle Miocene Kani Group (Okumura *et al.*, 1977); and an indeterminate teleoceratine from the upper Miocene Yagii Formation (Yoshida *et al.*, 1989). These Miocene Japanese rhinoceroses indicate a faunal connection of rhinoceroses between the mainland Eurasian continent and Japanese Islands during the Miocene.

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