

A new species of *Chilotherium* (*Perissodactyla*, *Rhinocerotidae*) from the Late Miocene of Qingyang, Gansu, China (Postprint)

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Full Text

A New Species of *Chilotherium* (*Perissodactyla*, *Rhinocerotidae*) from the Late Miocene of Qingyang, Gansu, China

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Abstract

An adult skull with articulated atlas and an adult mandible, collected by Emile Licent in 1920 from the Late Miocene of Qingyang (Gansu, China), are recognized as a new species, *Chilotherium licenti* sp. nov. These specimens possess typical characters of the genus *Chilotherium*, such as a strongly expanded mandibular symphysis, huge dagger-shaped i2s with an upturned medial flange, strongly constricted protocones, well-developed crochet and crista, and weakly developed parastyle folds and paracone ribs. *Chilotherium licenti* is characterized by the near absence of lingual and buccal cingula, and the formation of a medifossette on P2 to M2 by well-developed crochet and crista. The derived characters of the new species indicate that it represents a highly specialized taxon within the genus *Chilotherium*, corresponding to MN12–13 of the Turolian in Europe. Based on phylogenetic analysis of rhinocerotids, *C. licenti* from the Late Miocene is the most derived species among known members of the *Chilotherium* lineage.

Key words: Qingyang, Gansu; Late Miocene; Rhinocerotidae; *Chilotherium*

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1 Introduction

Emile Licent, a French Jesuit and naturalist, collected abundant fossils of the Hipparion fauna in Qingyang, Gansu Province, China in 1920 (Licent, 1936). However, among these collections, only the hyaenids (Qiu et al., 1979) and *Hipparion* (Qiu et al., 1987) have been systematically studied. *Chilotherium* is one of the most common genera in the Hipparion fauna in China, particularly abundant at fossil sites in Baode, Fugu, and Linxia (Deng, 2002), yet no detailed reports have addressed the *Chilotherium* material from Qingyang. Here we describe the rhinocerotid fossils collected by Licent nearly a century ago from Zhaojiacha (Tchao kia tch' a), a small village in Qingyang, Gansu [Figure 1: see original paper].

Since Ringström (1924) established the genus *Chilotherium*, 13 species have been described and 19 other species have been referred to this genus. According to Deng (2006), ten valid species are currently recognized: *C. primigenius*, *C. anderssoni*, *C. habereri*, *C. wimani*, and *C. xizangensis* from China; *C. schlosseri*, *C. samium*, *C. kowalevskii*, and *C. kiliasi* from Europe; and *C. persiae* from Iran. The material examined here represents a new derived species that expands our understanding of the genus' s evolutionary level and adaptive range.

The studied materials consist of one skull (TNP 03978) articulated with its atlas and one mandible (TNP 00328) housed in the Tianjin Natural History Museum. Osteological terminology follows Sisson (1953) and dental terminology follows

Qiu and Wang (2007). Specimens were measured using methods established by Guérin (1980). Phylogenetic analysis employed the craniodental data matrix of Antoine (2002), Antoine et al. (2003, 2010), and Lu (2013).

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2 Systematic Paleontology

Family Rhinocerotidae Owen, 1845

Subfamily Aceratheriinae Dollo, 1885

Tribe Chilotheriini Qiu et al., 1987

Genus *Chilotherium* Ringström, 1924

***Chilotherium licenti* sp. nov.** (Figs. 2-5)

Holotype: TNP 03978, a well-preserved adult skull with articulated atlas, lacking the premaxilla and occiput.

Referred specimen: TNP 00328, lower cheek teeth and i2s in situ, though most of the mandibular body is broken off.

Etymology: The specific epithet ‘licenti’ honors Emile Licent, the French Jesuit and naturalist who collected the specimens.

Type locality: Zhaojiacha (36°14 52.2 N, 107°46 31.3 E; elevation: 1168 m), Huachi County, approximately 60 km northeast of Qingyang City in Gansu Province, China [Figure 1: see original paper]. The specimens were collected from a brownish-red mudstone containing caliche nodules within the Hipparion Red Clay. The fossil-bearing bed is late Late Miocene in age (Baodean Asian Land Mammal Age).

Diagnosis: Nasals wide but gradually narrowing before the orbits; zygomatic arch fairly thin, particularly in its posterior portion; protocones and hypocones strongly constricted with straight lingual margins; crochet and crista well developed and linking to form a medifossette on P2-M2, with antecrochet also well developed; M1 possessing a projecting parastyle; lingual and buccal cingula nearly absent; buccal wall on upper premolars and M1 straight and smooth; posterior valleys of upper cheek teeth almost closed.

3 Description

Skull. TNP 03978 is well preserved except for the premaxilla and occiput [Figure 2: see original paper]. Cranial height measures 117 mm anterior to M3. In dorsal view, the widest transverse portion of the cranium occurs at the level of the postorbital process. The nasals are wide and particularly long (exceeding 81.3 mm), with a fine longitudinal groove along the prominent sagittal suture. The nasal surface is smooth without rugosity. Lateral margins lack obviously downturned edges, and the transverse section is half-lentoid. The nasals narrow gradually before the orbits, meaning the nasal base lacks constriction. The nasal tips are evidently truncated, positioned anterior to the DP1 level. The nasal notch is V-shaped (narrow and deep), with its posterior edge located at the M1/P4 boundary. The distance between the posterior edge of the nasal notch and the orbit is 72.2 mm.

Two infraorbital foramina are present: one dorsal to M1 near the lateral margin of the nasal notch, and another near the inferior margin of the nasal notch. The dorsal margin of the orbit is positioned high, with the anterior margin located at the anteroposterior plane of the middle of M2. The zygomatic arch is fairly thin, particularly posteriorly; its anterior end lies at the M2 level and its dorsal margin is curved. The dorsoventral height of the zygomatic arch is 54.9 mm at the anteroposterior level of the postorbital process. The postorbital processes on the frontal and zygomatic bones are comparatively weak. The palatal surface is smooth and widely arched. The basicranium is poorly preserved; the postglenoid process is broken with only the base preserved.

The temporal condyle is flat and straight. The glenoid cavity is deep, and the occipital crest is broken. The foramen magnum is onion-shaped with a pointed upper end. The missing premaxilla prevents determination of whether upper incisors were present; however, as a member of *Chilotherium*, they were probably reduced or absent.

Atlas. The fragmentary atlas is articulated with the skull, lacking the wings and caudal portion [Figure 3: see original paper]. The neural canal outline is mushroom-like, with alar notches present. The cranial articular fovea is comma-shaped, and the atlas centrum is intact, preserving the anterior portion of the axis dens.

Upper cheek teeth. The premolars (except DP1) and M1-M2 are moderately worn, while M3 is only slightly worn; all are hypsodont [Figure 4A: see original paper]. The upper cheek tooth row forms an almost straight line in the anterior portion of the cranium relative to the orbit. The ratio of upper premolar length (P3-P4) to molar length (M1-M3) is high at 85.2%. Cement on the buccal surface of upper cheek teeth is moderately developed. The buccal wall is straight and smooth on premolars and M1. On molars, the protocone is strongly constricted with a straight lingual margin.

DP1 is fairly small, round-triangular in shape, and deeply worn. P2 is nearly

quadrangular in occlusal view, with a parastyle and weak parastyle fold. The protocone and hypocone show no constriction and connect via a bridge; the hypocone is larger than the protocone and positioned posterior to the metacone. The protoloph is as buccally narrow as the metaloph and joins the ectoloph. The crochet and crista are well developed and link to form a medifossette. The lingual groove is shallowly U-shaped, the medial valley is closed, and the posterior valley is nearly closed. The lingual cingulum is weak and the buccal cingulum is absent.

P3 has a slightly projecting parastyle with weak parastyle fold and paracone rib, resulting in a straight, smooth buccal wall. The protocone is expanded with anterior and posterior constrictions, while the hypocone shows only slight anterior constriction. The protocone and hypocone connect via a bridge, with the protocone larger than the hypocone. The crochet and crista are well developed and link to form a medifossette. A lingual groove is present on the protocone; the medial and posterior valleys are closed. The lingual margin of the protocone is curved, and both lingual and buccal cingula are absent.

P4 is similar to P3 but larger. The hypocone is rounded without constriction and slightly larger than the protocone, which has a straight lingual margin.

M1 has a projecting parastyle. Its strongly constricted protocone has a flat lingual margin, while the hypocone shows only slight anterior constriction. The medial valley is narrow, and the sharp end of a fine antecrochet extends to the entrance of the medial valley. On the right M1, the crochet and crista are well developed but do not link to form a medifossette; the posterior valley is triangular and nearly closed. On the left M1, the crochet and crista link to form a medifossette. Both lingual and buccal cingula are absent.

M2 has a narrow, long parastyle and weakly developed paracone rib. It possesses slightly developed anterior and posterior cingula but no lingual cingulum. The protocone is expanded with anterior and posterior constrictions. In occlusal view, the small hypocone lacks constriction but has a vertical constricted groove on its anterior aspect. Features include a medifossette, open medial valley, V-shaped posterior valley, relatively narrow and long metastyle, and deep depression on the buccal wall of the metacone.

M3 is triangular in occlusal view because the ectoloph and metaloph are fused. It has a short, sharp parastyle, narrow protoloph, and ectometaloph. In the right M3, the hypocone is isolated, not linking to the ectometaloph. The protoloph is curved on the anterolingual side. The crochet is well developed but does not form a medifossette. The protocone has anterior and posterior constrictions, and the posterior cingulum is well developed.

Mandible. TNP 00328 preserves lower cheek teeth and i2s in situ, though most of the mandibular body is broken off [Figure 5: see original paper]. In dorsal view, the mandibular symphysis expands strongly laterally. In anterior view, the incisor alveolar margin is thin and sharp.

Lower teeth. The premolars and m1-m2 are deeply worn, while m3 is moderately worn [Figure 4B: see original paper]. The paraconid and paraloophid are not developed, and constrictions of the metaconid and entoconid are absent. The ectoflexid deepens gradually from base to crown. Cement on the buccal surface of lower cheek teeth is moderately developed. Lingual and buccal cingula are absent on lower cheek teeth except on m3.

The i2 is huge and dagger-shaped, with a round-triangular transverse section featuring an interior sharp angle; the root cross-section is oval. The i2 extends outward and upward.

No dp1 is preserved. The p2 is small and deeply worn, with a short, narrow protolophid and shallow ectoflexid. The metaconid is larger than the protoconid. The hypolophid is wider than the entolophid, and the metolophid is wider than the protolophid. The trigonid basin is nearly disappeared, and the talonid basin is V-shaped.

The p3 has a large trigonid and relatively small talonid, with a fairly short, wide protolophid, wide metolophid, and shallow ectoflexid. The hypolophid is wider than the entolophid. The trigonid basin forms a fairly small circle, while the talonid basin is sharply V-shaped due to deep wear.

The p4 is similar to p3 but larger.

The m1 is so deeply worn that the trigonid and talonid basins are nearly disappeared, except that the talonid basin of the left m1 remains sharply V-shaped. In occlusal view, the protolophid and hypolophid are nearly disappeared, while the metolophid and entolophid are comparatively wide. The ectoflexid is deep and sharply V-shaped.

The m2 has a round trigonid basin and V-shaped talonid basin. The metolophid is wider, the hypolophid is oblique, and the ectoflexid is deep and sharply V-shaped.

The m3 has a V-shaped trigonid basin and rectangular talonid basin. The protolophid is short and sharpens lingually. The hypolophid and entolophid are slightly narrow, with the hypolophid comparatively oblique. The ectoflexid is wide and deeply V-shaped. The lingual cingulum is developed but not continuous, forming a pillar at the lingual side of the talonid basin. The buccal cingulum is absent.

4 Comparison and Discussion

Many characters of these specimens, particularly in the mandible, are shared with species placed in *Chilotherium*. These include the gradually narrowing cranial dorsal surface before the orbits, the high position of the dorsal orbital margin, strongly constricted protocones, strongly broadening mandibular sym-

physis, and upturned medial flanges of i2s. However, the specimens represent a new species of *Chilotherium* with special characters distinct from known species.

The M3 of *C. persiae* is unique among *Chilotherium* species in its quadrangular occlusal surface (Ringström, 1924). Therefore, the triangular M3 of *C. licenti* distinguishes it from *C. persiae*. Meanwhile, *C. persiae* is usually larger than Chinese *Chilotherium* specimens; the distance between the nasal tip and occipital crest in an adult individual is approximately 630 mm. The external wall of upper cheek teeth in *C. kiliasi* undulates with a paracone fold underlined by two depressions (Geraads and Koufos, 1990), whereas that of *C. licenti* is flat. *C. schlosseri* and *C. samium* have well-developed cingula (Weber, 1904), but *C. licenti* has very reduced ones. In *Chilotherium*, the premolar series is shorter than the molar series, particularly in *C. kowalevskii* (Pavlov, 1913). The crochet on molars of *C. schlosseri* is elongate, reaching the ectoloph to form a medifossette. However, on P2 to M2 of *C. licenti*, the crochet and crista are well developed and link together to form a medifossette—a unique character among the ten valid species of *Chilotherium*.

Chilotherium anderssoni, the type species of the genus, was described by Ringström in 1924. That species has a U-shaped nasal notch, weak crochet on M3, weak crochet and crista on P2 (not linking to form a medifossette), and a continuous lingual cingulum on the premolars. In contrast, *C. licenti* has a V-shaped nasal notch, nearly absent labial and buccal cingula on the premolars, and medifossettes present from P2 to M2. *C. licenti* has a flat cranial dorsal profile, thin dorsal orbital margin, narrow nasals, and flat outer walls of cheek teeth—features obviously more derived than those of *C. primigenius*, *C. wimani*, and *C. xizangensis*. Furthermore, *C. licenti* is somewhat larger than these three Chinese species, as shown in Table 1. Measurements of the cheek teeth of *C. licenti* sp. nov. compared with other *Chilotherium* species appear in Table 2.

The upper cheek teeth of *C. licenti* show derived characters distinguishing them from *C. wimani*, including a flat buccal wall almost without a paracone rib or parastyle fold, and strongly constricted protocones and hypocones. *C. primigenius*, an early Late Miocene species (Deng, 2006), has primitive characters distinct from *C. licenti*. *C. xizangensis* resembles *C. wimani* in having a saddle-backed cranial dorsal profile, projecting anterior and thick dorsal orbital margins, low crown, and marked parastyle folds (Ji et al., 1980; Deng, 2001a). This new species differs evidently from *C. habereri* based on upper cheek tooth characters. In *C. licenti*, lingual and buccal cingula on premolars are nearly absent and medifossettes are present on P2–M2, whereas in *C. habereri* the cingula are continuous and a medifossette occurs only on premolars, not on molars (Ringström, 1924).

Consequently, *C. licenti* is a new species distinct from all known *Chilotherium* species. It possesses unique characters: nearly absent lingual and buccal cingula (differentiating it from relatively primitive species), well-developed crochet and crista linking to form a medifossette on P2–M2, and strongly constricted protocone. These characters are more derived than in any other known *Chilotherium*

species.

According to Licent's diary entry (1924), the skull with articulated atlas and the mandible were found in the same place. However, our observations and measurements reveal that the upper cheek teeth are much less worn than the lower teeth, with the upper cheek tooth row measuring 190 mm in length versus 200 mm for the lower row. Crown height comparisons between upper and lower cheek teeth appear in Table 3. Given that wear on upper cheek teeth proceeds much faster than on lower cheek teeth in *Chilotherium* individuals (Deng, 2001b), the skull and mandible likely do not belong to a single individual but represent two adult individuals (hence the two specimen numbers). Ringström (1924) noted that isolated dentitions from *Chilotherium* cannot be easily identified. Although the new mandibular specimen differs from other *Chilotherium* species, because the skull and mandible were found together, we attribute the mandibular specimen to *C. licenti*.

The tendency toward absent cingula and the high, flat crown surface indicate that *C. licenti* may have remained a brush feeder but with increasing adaptation to hard, dry bush vegetation. Well-developed secondary structures on cheek teeth and increased molar crown height are indicators of a shift toward a more abrasive diet. We infer that the Late Miocene rhino *C. licenti* grazed in an open steppe habitat. To adapt to the arid environment of the Late Miocene (Deng, 2004), *C. licenti* appears to have developed derived features.

This new Late Miocene species shares many characters with other *Chilotherium* species but displays a highly specialized morphotype. Compared with *C. anderssoni* and *C. habereri*, *C. licenti* is characterized by a V-shaped nasal notch, nearly absent buccal and lingual cingula, medifossettes on P2-M2 formed by well-developed crochet and crista, metaloph constriction on P2-P4, and the base of the antecrochet spreading toward the entrance of the median valley. These characters are more derived than those of *C. anderssoni* and *C. habereri*.

Heissig (1989) considered that *Chilotherium* emerged during the early Middle Miocene of South Asia from *Subchilotherium* in the lower Siwalik series. *C. primigenius* is the earliest and most primitive species in the genus from the early Late Miocene, corresponding to early and middle MN 9 (Deng, 2006). *Chilotherium wimani* was the most abundant taxon in the Late Miocene "Hipparion fauna" of the Linxia Basin; its first appearance was necessarily later than that of *C. primigenius* but must precede that of other *Chilotherium* species (Deng, 2006). The type species, *C. anderssoni*, is abundant in the Baode fauna correlated with MN12. Liu et al. (1978) reported *C. habereri* from the (Miocene) Gongwangling locality (Lantian, Shaanxi) dated to 6.6 Ma (Zhang et al., 2013).

In conclusion, the first appearance of *C. licenti* correlates with MN12-13 of the Turolian in Europe. The Qingyang Hipparion fauna contains abundant fossils including *H. hippidiodus* and *H. coelophyes*. Compared with *Hipparion* species at Baode, the Qingyang *H. hippidiodus* and *H. coelophyes* appear more derived, as indicated by their smaller body size, reduced preorbital fossa, and

other features (Qiu et al., 1987). Qiu et al. (1979) systematically studied the late Late Miocene hyaenids, including *Adcrocuta eximia variabilis*, *Ictitherium robustum gaudryi*, *I. wongii*, and other species collected by Emile Licent from Xinjiagou and Zhaojiacha (Qingyang, Gansu) in 1920. Based on these shared species, the Qingyang Hipparion fauna has been correlated with MN12 (Qiu and Qiu, 1990). Therefore, the earliest possible date for *C. licenti* correlates with MN12 of the Turolian in Europe, and *C. licenti* from the late Late Miocene is the most derived species described thus far in the genus *Chilotherium*.

6 Phylogenetic Analysis

We performed a phylogenetic analysis to assess the phylogenetic position of *Chilotherium licenti* using the data matrix of Lu (2013, Appendix A-2) with the new species added (Appendix 1). The matrix includes 23 taxa and 214 characters [Figure 6: see original paper]. To ensure data availability, we deleted some taxa from Lu's (2013) matrix, such as "*Aceratherium huadeensis*" and other poorly preserved or taxonomically controversial materials. Meanwhile, we retained the type species of the genus, *C. anderssoni*, and added the earliest and most primitive species, *C. primigenius*. *Trigonias osborni* served as the outgroup.

Phylogenetic analysis was performed using traditional search in TNT (Version 1.1) (Goloboff et al., 2008) with all characters equally weighted. The analysis generated one most parsimonious tree with a tree length of 620 steps, a consistency index of 0.355, and a retention index of 0.524.

Chilotherium licenti shares many synapomorphies with other genus members, including a narrow zygomatic arch, gradually narrowing cranial dorsal surface rostral to the orbit, strong broadening of the mandibular symphysis, well-developed secondary structures on cheek teeth, comparatively small P2, and upturned medial flanges of i2. These features support *C. licenti* as a member of *Chilotherium*. *Chilotherium licenti* is the sister taxon of *C. anderssoni*, and both are more derived than *C. primigenius*. In *C. primigenius*, the ventral surface of the mandibular symphysis is flat, and the parietal crests are not well separated, forming a sagittal crest—features that differ from other species (Deng, 2006). Meanwhile, *C. licenti* is characterized by medifossettes from P2 to M2 formed by well-developed crochet and crista, and nearly absent lingual and buccal cingula, distinguishing it from other *Chilotherium* species.

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References

- Antoine P O, 2002. Phylogénie et évolution des Elasmotheriina (Mammalia, Rhinocerotidae). *Mém Mus Natl Hist Nat*, 188: 1-350.
- Antoine P O, Duranthon F, Welcomme J, 2003. *Alicornops* (Mammalia, Rhinocerotidae) dans le Miocène supérieur des collines Bugti (Balouchistan, Pakistan): implications phylogénétiques. *Geodiversitas*, 25: 575-603.
- Antoine P O, Downing K F, Crochet J Y et al., 2010. A revision of *Aceratherium blanfordi* Lydekker, 1884 (Mammalia: Rhinocerotidae) from the Early Miocene of Pakistan: postcranials as a key. *Zool J Linn Soc*, 160: 139-194.
- Deng T, 2001a. New materials of *Chilotherium wimani* (Perissodactyla, Rhinocerotidae) from the Late Miocene of Fugu, Shaanxi. *Vert PalAsiat*, 39: 129-138.
- Deng T, 2001b. Cranial ontogenesis of *Chilotherium wimani* (Perissodactyla, Rhinocerotidae). In: Deng T, Wang Y eds. *Proceedings of the 8th Annual Meeting of the Chinese Society of Vertebrate Paleontology*. Beijing: China Ocean Press. 101-112.
- Deng T, 2002. Limb bones of *Chilotherium wimani* (Perissodactyla, Rhinocerotidae) from the Late Miocene of the Linxia Basin in Gansu, China. *Vert PalAsiat*, 40: 305-316.
- Deng T, 2004. Evolution of the Late Cenozoic mammalian faunas in the Linxia Basin and its background relevant to the uplift of the Qinghai-Xizang Plateau. *Quat Sci*, 24: 413-420.
- Deng T, 2006. A primitive species of *Chilotherium* (Perissodactyla, Rhinocerotidae) from the Late Miocene of the Linxia Basin (Gansu, China). *Cainoz Res*, 5: 93-102.
- Geraards D, Koufos G, 1990. Upper Miocene Rhinocerotidae (Mammalia) from Pentaloph-1, Macedonia, Greece. *Palaeontogr Abt A*, 210: 151-168.
- Goloboff P A, Farris J S, Nixon K C, 2008. TNT, a free program for phylogenetic analysis. *Cladistics*, 24: 774-786.
- Guérin C, 1980. Les rhinocéros (Mammalia, Perissodactyla) du Miocène terminal au Pleistocène supérieur en Europe occidentale: comparaison avec les espèces actuelles. *Doc Lab Géol Lyon*, 79: 1-1182.

- Heissig K. 1989. Rhinocerotidae. In: Prothero D R, Schoch R M eds. *The Evolution of Perissodactyls*. New York: Oxford University Press. 399-417.
- Ji H X, Xu Q Q, Huang W B, 1980. The Hipparion fauna from Guizhong Basin, Xizang. In: the Chinese Academy of Sciences ed. *The Comprehensive Scientific Expedition to the Qinghai-Xizang Plateau*. Beijing: Science Press. 18-27.
- Licent E, 1924. *Comptes-Rendus de dix années (1914-1923)*. Tianjin: Musée Hoangho-Paiho.
- Licent E, 1936. *Vingt deux années d' exploration dans le Nord de la Chine, en Mandchourie, en Mongolie et au Bas-Tibet (1914-1935)*. Pub Mus Hoang Ho Pai Ho, 39: 1-41.
- Liu T S, Li C K, Zhai R J, 1978. Pliocene vertebrates of Lantian, Shensi. *Profes Pap Stratigr Palaeont*, 7: 149-200.
- Lu X K, 2013. A juvenile skull of *Acerorhinus yuanmouensis* (Mammalia: Rhinocerotidae) from the Late Miocene hominoid fauna of the Yuanmou Basin (Yunnan, China). *Geobios*, 46: 539-548.
- Pavlov M, 1913. Mammifères Tertiaires de la nouvelle Russie. *Novv Mém Soc Imp Nat Moscou*, 17: 1-68.
- Qiu Z X, Qiu Z D, 1990. Neogene local mammalian faunas: succession and ages. *J Stratigr*, 14: 241-260.
- Qiu Z X, Wang B Y, 2007. Paraceratheres fossils of China. *Palaeont Sin*, Ser C, 29: 1-396.
- Qiu Z X, Huang W L, Guo Z H, 1979. Hyaenidae of the Qingyang Hipparion fauna. *Vert PalAsiat*, 17: 200-221.
- Qiu Z X, Huang W L, Guo Z H, 1987. The Chinese hipparionine fossils. *Palaeont Sin*, Ser C, 25: 1-250.
- Ringström T, 1924. Nashorner der Hipparion-fauna Nord Chinas. *Palaeont Sin*, Ser C, 1: 1-159.
- Sisson S B, 1953. *The Anatomy of the Domestic Animals*. Philadelphia: Saunders W B Company. 1-972.
- Weber M, 1904. Ueber Tertiäre Rhinocerotiden von der Insel Samos. *Bull Soc Imp Nat Moscou*, 17: 477-501.
- Zhang Z Q, Kaakinen A, Liu L P et al., 2013. Mammalian biochronology of the Late Miocene Bahe Formation. In: Wang X M, Flynn L J, Fortelius M eds. *Fossil Mammals of Asia: Neogene Biostratigraphy and Chronology*. New York: Columbia University Press. 203-217.

Supplementary Material

Supplementary material can be found on the website of *Vertebrate PalAsiatica* (http://english.ivpp.cas.cn/sp/PalAsiatica/vp_list/) in Vol. 56.

Appendix 1. Character codes of *Chilotherium licenti* (characters after Lu, 2013).

Chilotherium licenti (TNP 03978): 0???001001 -0112?1110 1?1-1111-0
1?10?0013- ??0?100000 3-1011???? 0-0-0-01?? ??????0??? ??0?0?????
?????11??? 121??????? 112100000?

Note: Figure translations are in progress. See original paper for figures.

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