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SHORT COMMUNICATION

A NEW EARLY EOCENE ARCTOSTYLOPID (ARCTOSTYLOPIDA, MAMMALIA) FROM THE ERLIAN BASIN, NEI MONGOL (INNER MONGOLIA), CHINA

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Fossil mammals from the Bumbanian Asian Land Mammal Age are critical for understanding mammalian faunal turnover across the Paleocene–Eocene (P–E) transition in Asia. The Bumbanian fauna is characterized by fossils from the Bumban Member of the Naran Bulak Formation in Mongolia (Russell and Zhai, 1987). Bumbanian faunas were undocumented in Inner Mongolia, China until the recent discovery of a typical Bumbanian gliriform mammal, *Gomphos elkema*, in the Huheboerhe area of the Erlian Basin (Meng et al., 2004). Here, we report another mammalian species from the same bed, representing an arctostylopid in the fauna.

Arctostylopidae, an extinct mammalian group, have been reported from the Paleocene and early Eocene of Asia and North America (McKenna and Bell, 1997; Zack, 2004). Among 15 named species of Asian arctostylopids, most have been recovered in association with typical Paleocene mammal assemblages of Gashatan or Nongshanian age (Matthew and Granger, 1925; Matthew, Granger, and Simpson, 1929; Tang and Yan, 1976; Chow and Qi, 1978; Zheng, 1979; Zheng and Huang, 1986; Nessov, 1987; Huang and Chen, 1997; Huang and Zheng, 1997; Meng, Zhai, and Wyss, 1998; Huang, 2003; Huang and Zheng, 2003; Kondrashov and Lucas, 2004). Only a few arctostylopids have been reported previously from early Eocene rocks in China (Zhai, 1978; Huang, Zheng, and Ding, 2001; Tong and Wang, 2006), none of which has been unequivocally assigned to the Bumbanian age. Dashzeveg (1982:277) mentioned the occurrence of *Arctostylops* in the Bumban Member of the Naran Bulak Formation of Mongolia, but this record has never been confirmed. The arctostylopid reported here therefore provides the first solid evidence for the occurrence of this group in Asian Bumbanian faunas.

The ordinal position of Arctostylopidae remains in dispute. When he described *Arctostylops steini* from the North American Paleocene, Matthew (1915) referred it to Entelonychia, a primitive group of notoungulates. Cifelli, Schaff, and McKenna (1989) reviewed the known arctostylopid taxa and proposed a new order, Arctostylopida, for the family. Discovery of a semi-articulated partial skeleton of *Arctostylops* from the North American Clarkforkian led to reconsideration of the relationship between arctostylopids and South American notoungulates (Bloch, 1999). Kondrashov and Lucas (2004) reasserted the close relationship between arctostylopids and true notoungulates, but this proposal was disputed by Missiaen et al. (2006). Because the phylogenetic position of Arctostylopidae in relation to Notoungulata and other mammalian orders has not yet been established, and because our new specimens do not provide further evidence to clarify the issue, we provisionally leave the Arctostylopidae in its own order Arctostylopida, as proposed by Cifelli, Schaff, and McKenna (1989).

In describing the new material of arctostylopids, we use the cusp nomenclature for arctostylopid molars proposed by Cifelli, Schaff, and McKenna (1989) and modified by Kondrashov and Lucas (2004), with two exceptions. Cifelli, Schaff, and McKenna (1989:fig. 1) termed a crest, extending from the pseudohypocone to the metaconule, as the postprotocrista. Based on its relationship to the pseudohypocone, a more appropriate name for this crest would be the postpseudohypocrista. Kondrashov and Lucas (2004) use the term parastylid to replace Cifelli et al.'s paracristid for the anteroexternally extended cristid. Because no distinct cuspid exists at the end of this cristid, it is more informative to call it the anterobuccal cristid.

SYSTEMATIC PALEONTOLOGY

Order ARCTOSTYLOPIDA Cifelli, Schaff, and McKenna, 1989
Family ARCTOSTYLOPIDAE Schlosser, 1923
Genus *ANATOLOSTYLOPS* Zhai, 1978

Type Species—*Anatolostylops dubius* Zhai, 1978
Included Species—*Anatolostylops dubius* Zhai, 1978, and *A. zhaii* sp. nov.
Emended Diagnosis—Differs from all other known arctostylopid genera in having the following combination of characters: Relatively large arctostylopid; molars high crowned; ectoloph straight and moderately elongate, crests of protocone and pseudohypocone connecting and forming a relatively deep and enclosed fossette, no ectocingulum; entocristid contacting ectolophid and oriented nearly transversely; ectolophid joining the trigonid at metaconid, ectoflexid deep and relatively wide.
Distribution—Early Eocene, Xinjiang and Inner Mongolia, China.

ANATOLOSTYLOPS ZHAII sp. nov.
(Figs. 1–5)

Holotype—Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) specimen V 14657, a right maxilla fragment with M2, lingual halves of P4 and M1, and roots of M3 (Fig. 1).
Hypodigm—IVPP V 14633.1, a right maxilla fragment with lingual halves of P4–M3; IVPP V 14633.2, a right maxilla frag-

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ment with lingual half of M2; IVPP V 14633.3, a right lower jaw fragment with broken m3; IVPP V 14633.4, a right lower jaw fragment with roots of m1 and posterior root of p4; IVPP V 14634, a left m1; IVPP V 14635, a left lower jaw fragment with posterior part of m2 and anterior part of m3; IVPP V 14658.1, a left maxilla fragment with lingual halves of M3 and roots of M2; IVPP V 14658.2, a right lower jaw fragment with m2 and posterior part of m1 talonid; IVPP V 14659, a right maxilla fragment with M2–3 and roots of M1.

Horizon and Localities—All specimens are from the *Gomphos*-bearing bed in the upper part of the Nomogen Formation, which is considered to be Bumbanian in age (Meng et al., 2004, 2007). The holotype, V 14633, and V 14658 were collected at Nuhetingboerhe, which is probably the Central Asiatic Expedition (CAE) locality 6 miles west of Camp Margetts. V 14634, V 14635, and V14659 were found at Wulanboerhe (formerly Ulan Bulak), which is probably the CAE locality 7 miles southwest of Camp Margetts (Meng et al., 2007). Both localities are in the Erlian Basin, Inner Mongolia, People's Republic of China.

Diagnosis—Differs from the type species in having slightly lower crowns, a complete lingual cingulum, a stronger parastyle fold, a less elongate ectoloph, and a proportionally smaller M3 relative to M2.

Etymology—The species is named after Prof. R.-J. Zhai, who described the first Eocene arctostylopid, the type species of *Anatolostylops*.

Description—The maxillae are very fragmentary, but a couple of features can be observed. The anterior root of the zygomatic arch begins at a point buccal to the midpoint of M2, and the relatively large infraorbital foramen on the type specimen lies above the junction between P4 and M1. A fragmentary right lower jaw (V 14658.2) shows a curved lower border.

Each of the preserved upper cheek teeth (P4–M3) has three roots. Only the lingual halves of P4 are preserved on V 14657 and V 14658.1. Both have a continuous lingual cingulum.

The M1 on the type specimen only has its lingual half preserved. It is much smaller than M2. Its crown has an enclosed fossette. The lingual cingulum is continuous with crenulations. A distinct sulcus exists on the lingual side between the protocone and the pseudohypocone (Fig. 1). The preserved lingual half of M1 on V 14633.1 is similar to that of the type specimen, but its cingula are narrower and lack crenulations and there is no sulcus on the lingual side between protocone and pseudohypocone. M2 is the largest in the tooth row. On the holotype (V 14657), the M2 is nearly complete except for damage at the posterior end of the ectoloph. It has a relatively high crown, which is trapezoidal in occlusal view, with the buccal part distinctly longer than its lingual counterpart. The lingual side of its upper crown shifts buccally. The crests derived from the protocone and pseudohypocone connect to each other on the lingual side of the crown and form a relatively deep fossette with the ectoloph. The fossette persists through considerable wear. A parastyle fold exists on the straight ectoloph, but no trace of ectocingulum is visible on the buccal side of the crown. The precingulum, postcingulum, and lingual cingulum are well developed and continuous on the lingual side with some crenulations (Fig. 1). On V 14659, a complete M2 is also preserved, but its crown is heavily worn, and the enclosed fossette has disappeared. This tooth is slightly larger than that of the type specimen and it displays similar morphology to the latter, although minor differences from the type exist, such as a weaker parastyle fold, the elongate parastyle, and the narrower lingual cingulum bearing no crenulations (Fig. 2). Only the lingual halves of two other M2s (V 14633.1, V 14633.2) are preserved. Their crown morphology also resembles that of the type specimen, except for their smaller size, proportionally narrower crown (Table 1), and narrower lingual cingulum without crenulations. The crown of M3 on the type specimen is almost completely broken away, except for the well-developed precingulum

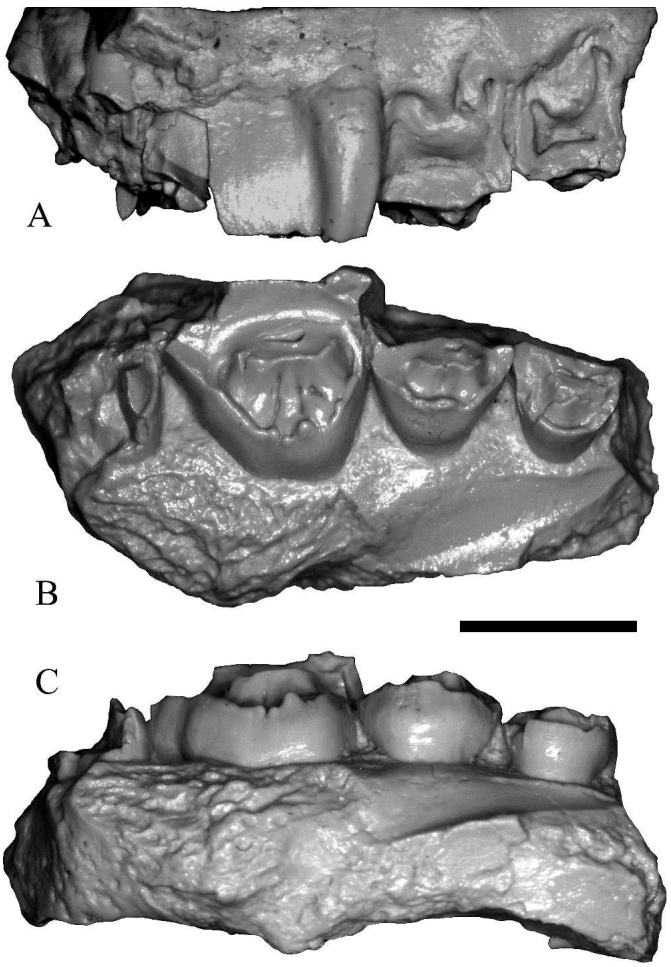

FIGURE 1. Right maxilla of *Anatolostylops zhaii* sp. nov. IVPP V14657 (Holotype). **A**, buccal view; **B**, crown view; **C**, lingual view. Scale bar equals 5 mm.

(Fig. 1). The M3 crown of V 14659 is mostly preserved, although its posterobuccal corner is missing. This tooth is about the same size as that of the type specimen. Although it is heavily worn, the small fossette is still visible. The precingulum, postcingulum, and lingual cingulum are continuous without crenulations. Its parastyle is similar to that of the preceding M2 (Fig. 2). M3s of V 14633.1 and V 14658.1 are proportionally smaller than those of V 14657 and V 14659, as indicated by the preserved lingual halves and external roots (Table 1). Both have a small fossette on the crown. The cingula are continuous on the lingual side, which is well preserved in V 14658.1.

All the lower molars are double-rooted. The m1 of V 14634 is complete. Its trigonid is short, with distinct paracristid and anterobuccal cristid. The metaconid is distinctly larger than the protoconid. The talonid is much longer than the trigonid. The entolophid, originating from the entoconid, extends slightly anterobuccally to contact the ectolophid and divides the talonid into two parts: the talonid notch and talonid basin. The ectocingulid is buccal to the protoconid and the anterior part of the talonid, and the lingual cingulid extends forward from the base of the talonid notch and is confluent with the anterobuccal cristid (Fig. 3). On V 14658.2, the posterior part of the talonid of m1 and a nearly complete m2 are preserved. The talonid of m1 is the same as that of V 14634 in both size and structure. The m2 on V 14658.2 is distinctly larger than m1 (Table 1). Its morphology is basically the same as that of m1. Compared to m1, the m2 talonid

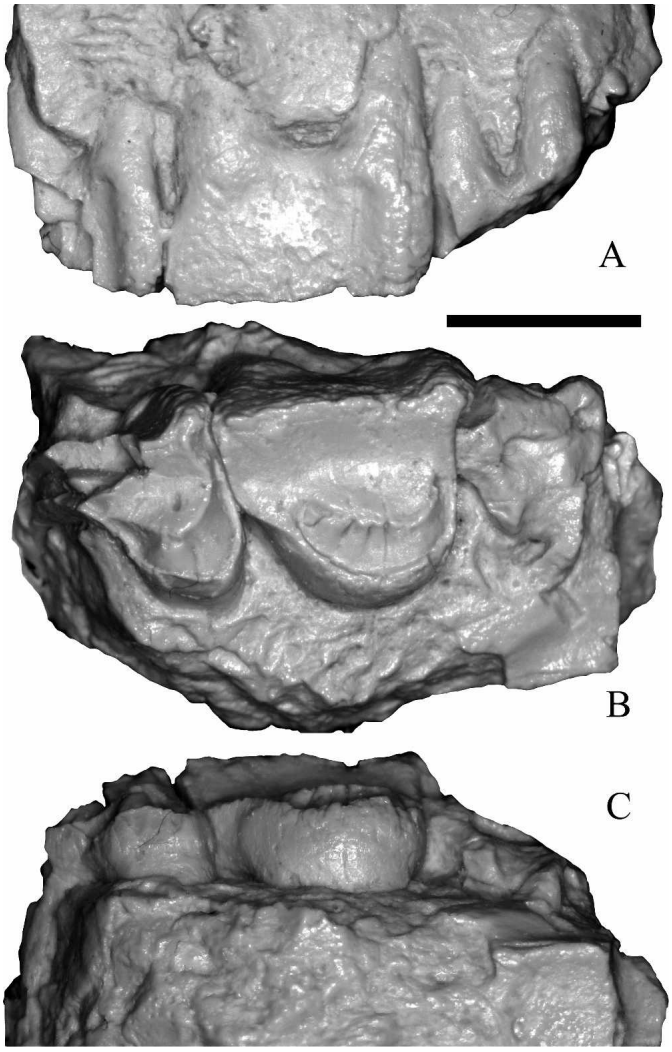

FIGURE 2. Right maxilla of *Anatolostylops zhaii* sp. nov. IVPP V14659. **A**, buccal view; **B**, crown view; **C**, lingual view. Scale bar equals 5 mm.

basin is proportionally larger; the paraconid is more salient; and the entolophid is transversely oriented (Fig. 4). The preserved lingual part of the m2 talonid on V 14635 shows the same features as that of V 14658.2. The m3 on V 14635 is badly damaged, but some critical features are recognizable. These features include the presence of a small paraconid, the presence of lingual

TABLE 1. Measurements of teeth of *Anatolostylops zhaii* sp. nov. (in mm).

Specimen	P4L	P4W	M1L	M1W	M2L	M2W	M3L	M3W
V 14657	3.50*	3.50*	4.25*	4.30*	6.80	5.90	4.10*	5.00*
V 14633.1	3.50*	3.75*	4.40*	3.80*	6.35*	4.75*	3.70*	4.10*
V 14633.2					6.20*	4.70*		
V 14658.1							4.00	4.20*
V 14659			4.50*	5.45*	6.95	6.20	4.10*	5.10
			m1L	m1W	m2L	m2W	m3L	m3W
V 14633.3							6.75*	2.35*
V 14634			5.45	2.30				
V 14635						3.30*	6.85*	2.85
V 14658.2				2.35	6.75	2.80		

*Indicate estimated values for the broken teeth.

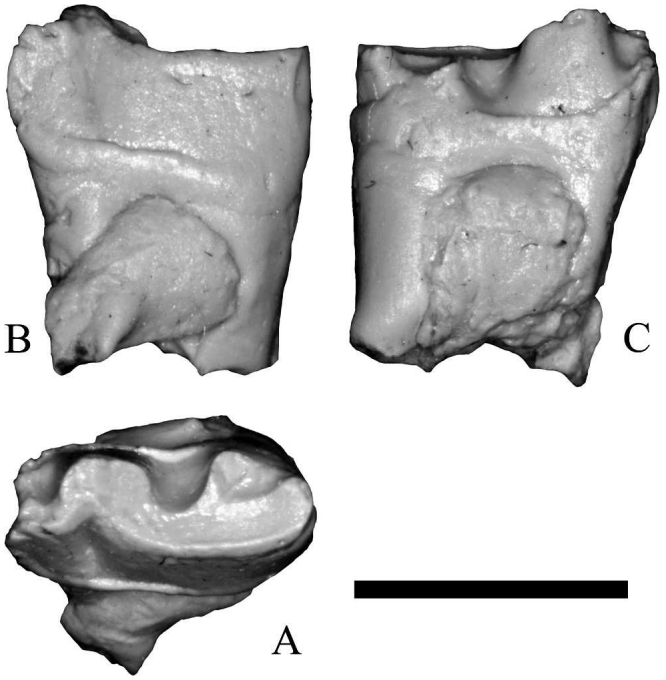

FIGURE 3. Left m1 of *Anatolostylops zhaii* sp. nov. IVPP V14634. **A**, crown view; **B**, buccal view; **C**, lingual view. Scale bar equals 5 mm.

and buccal cingulids, a wide and deep ectoflexid, and the ectolophid connecting to the metaconid. Its talonid is narrower than the trigonid and tapers posteriorly (Fig. 5). The poor preservation of V 14633.3 does not allow crown features of m3 to be discerned, but a narrow and posteriorly tapered talonid is indicated by the outline of m3.

Discussion—The upper cheek teeth assigned here to *Anatolostylops zhaii* show some variation in the development of the parastyle fold, development of crenulations on the lingual cingulum, and overall size. Given the small size of the collection, it cannot yet be determined whether such differences represent intraspecific variation or taxonomically significant traits. Because these differences are considered to be minor, we regard them as intraspecific variation. None of the lower molars was found in direct association with the uppers, but their size and some morphological characteristics, including their high crowns and well-developed cristids, match features observed in the upper teeth. These factors, plus the rarity of arctostylopids at this stratigraphic level, lead us to refer upper and lower dentitions from the *Gomphos*-bearing bed in the Erlian Basin to the same species.

The new arctostylopid can easily be distinguished from all known Paleocene arctostylopids by its larger size, higher crowned cheek teeth, better-developed crests, straight and flat ectoloph on upper molars, and less-developed paracone fold. An unnamed arctostylopid from the North American Eocene, represented by a left M2 (Zack, 2004), differs from the new specimens in being smaller, having less developed cingula, a proportionally wider crown, and a less elongate ectoloph. *Stenostylops xiangensis*, cited as Arctostylopidae genus and species indet. A by Cifelli, Schaff, and McKenna (1989:26), from the early Eocene Jianjiaxi Formation of Hunan, China is characterized by a straight and very elongate ectoloph, and the tooth width much smaller than length (Huang, Zheng, and Ding, 2001), and is therefore significantly different from *A. zhaii*. In addition, *Stenostylops* is much smaller than the new arctostylopid. *Migrostylops* from the Eocene Wutu Formation of Shangdong, China is

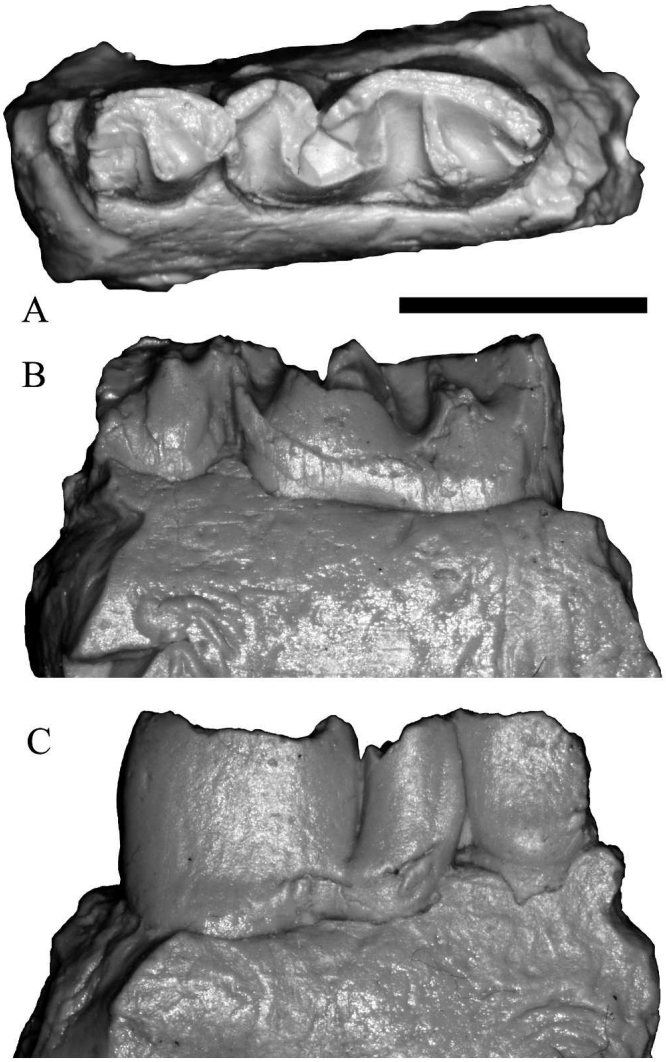

FIGURE 4. Right lower jaw of *Anatolostylops zhaii* sp. nov. IVPP V14658.2. **A**, crown view; **B**, lingual view; **C**, buccal view. Scale bar equals 5 mm.

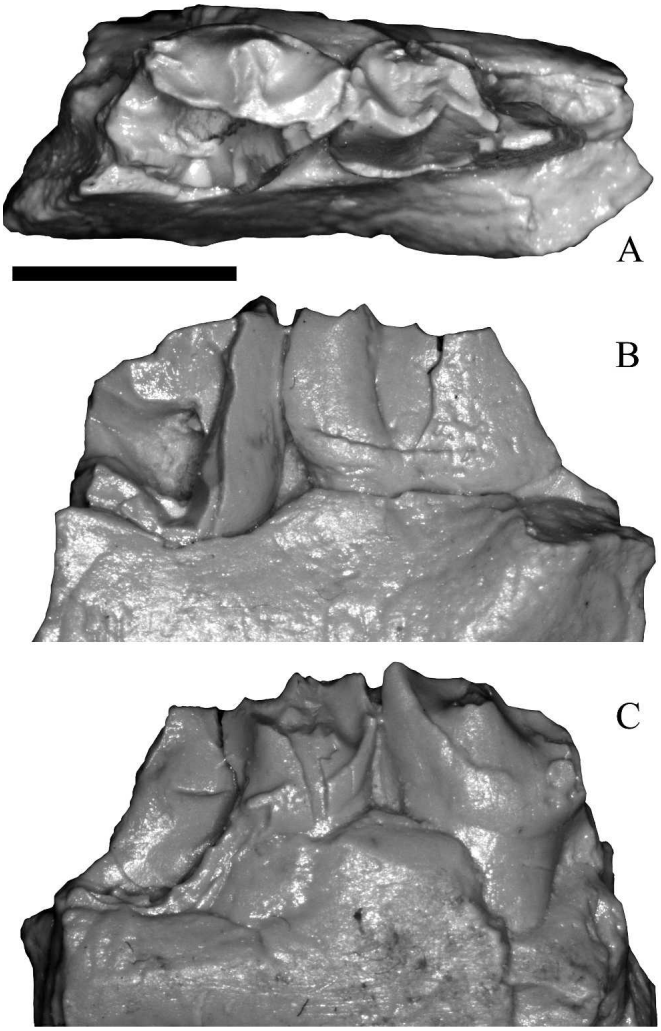

FIGURE 5. Left lower jaw of *Anatolostylops zhaii* sp. nov. IVPP V14635. **A**, crown view; **B**, buccal view; **C**, lingual view. Scale bar equals 5 mm.

similar to North American *Arctostylops* (Tong and Wang, 2006). It differs from *A. zhaii* in being smaller, having better-developed paracone fold, upper molars wider than long, greatly reduced trigonids, and ectolophid connecting to protoconid.

The upper molars of *A. zhaii* are most similar to those of *Anatolostylops dubius* from the Eocene Shisanjianfang Formation of Xinjiang, China (Zhai, 1978) in sharing a similar size; high crowns; straight and moderately elongate ectoloph, deep and enclosed fossette on the crown, and absence of the ectocingulum. *A. zhaii* differs from *A. dubius* in having slightly lower crown height, a complete lingual cingulum, a stronger paracone fold, a less elongate ectoloph, and a smaller M3 relative to M2. The similarities indicate that they are congeneric, but the differences clearly separate them as two species. Because the type species is only represented by a left maxilla with M2–3, the lower dental features of *A. zhaii* can now be added to the diagnosis of the genus.

Zheng (1979) and Huang and Chen (1997) classified the known arctostylopid taxa into two subfamilies, the Asiostylopinae and the Arctostylopinae, based on non-comprehensive comparison of dental features. Cifelli, Schaff, and McKenna (1989) grouped *Sinostylops* and *Bothriostylops* in one clade, and *Arctostylops*, *Palaeostylops*, *Gashatostylops*, *Anatolostylops*, and *Stenostylops* in another. In this paper, we follow Huang and Chen (1997) and Kondrashov and Lucas (2004) in regarding *Gashatostylops* as a junior synonym of *Palaeostylops*. Because most arctostylopid specimens are fragmentary, a thorough phylogenetic analysis of this group has not yet been conducted. The specimens of *Anatolostylops* from the Erlian Basin do not resolve the relationships of arctostylopids with respect to other mammals; however, they do provide new information on the relationships of some arctostylopid genera. A close relationship between *Anatolostylops* and *Stenostylops* is supported by the shared distribution of some features, such as a straight and flat ectoloph, enclosed fossette, and M2 distinctly longer than wide. The lower molars of *Anatolostylops*, *Sinostylops*, *Bothriostylops*, and *Kazachostylops* are similar in having a wide and deep ectoflexid, the ectolophid reaching the metaconid, and an unreduced m3 with a narrow talonid. Pending a cladistic analysis, we suspect that these genera can be grouped together. On the other hand, *Arctostylops*, *Palaeostylops*, and *Migrostylops* may represent a different lineage, as indicated by their uniquely specialized dental characters, including an extremely reduced trigonid, ectolophid reaching the protoconid, M2 wider than long, and a well-developed pseudohypocone.

ASSOCIATED MAMMALIAN FOSSILS AND BIOSTRATIGRAPHIC CORRELATION

Two mammalian species, the gliriform *Gomphos elkema* and the euprimate *Baataromomys ulaanus*, have been reported from the *Gomphos*-bearing bed in the Erlian Basin, Inner Mongolia, China (Meng et al., 2004; Ni et al., 2007). Other undescribed forms, associated with *Anatolostylops zhaii* sp. nov., include two perissodactyls, *Pataecops* sp. and ?*Homogalax* sp., several species of rodents, a lagomorph, a mesonychid, a creodont, and a possible artiodactyl. *Gomphos elkema* was only documented from the Bumban Member of the Naran Bulak Formation and its equivalent in Mongolia (Dashzeveg, 1988), before its recent discovery in the Erlian Basin (Meng et al., 2004). The generic status of *Homogalax namadicus* from the Mongolian Bumban Member (Dashzeveg, 1979) remains undetermined (Ting, 1998; Hooker and Dashzeveg, 2004; Lucas and Kondrashov, 2004), but its type specimen and upper molars of ?*Homogalax* sp. from the Erlian Basin are morphologically similar. Specimens of several ctenodactyloid rodents have been collected from the *Gomphos*-bearing bed by screenwashing. Some rodent teeth are similar to those reported from the Bumban Member (Dashzeveg, 1990), but detailed comparisons are hindered by the poor descriptions and illustrations in the original study. In addition, the taxonomy of Bumban rodents is problematic (Averianov, 1996). The rodents in our collection are also similar to *Cocomys lingchaensis* (Li, Zheng, and Ting, 1979). This mammalian assemblage indicates a Bumbanian age for the *Gomphos*-bearing bed in the Erlian Basin.

The occurrence of *Pataecops* remains problematic. *Pataecops parvus*, from the Kolobolchi Formation at the locality called "five miles north of Orok Nor," was considered to be an element of the Irdinmanhan fauna (Russell and Zhai, 1987). However, none of the mammals from the Kolobolchi Formation was reported to be unambiguously associated with *Pataecops parvus*. Coexistence of *Pataecops* and the Bumbanian forms requires a reconsideration of its biostratigraphic provenance. In addition, erroneous stratigraphic data associated with earlier collections of Arshantan and Irdinmanhan faunas may have complicated previous efforts to correlate Eocene faunas on the Mongolian Plateau (Meng et al., 2007).

Anatolostylops dubius was reported from the lower Eocene Shisanjianfang Formation of Xinjiang, China, but because of lingering uncertainty regarding the stratigraphic occurrence of the fossil, the possibility of its being from the lower Oligocene in that region was mentioned by Zhai (1978:107) and Russell and Zhai (1987). This possible complication failed to draw much attention, except that Cifelli, Schaff, and McKenna (1989:22) cited Zhai as a personnel communication. *A. dubius* has been widely cited as a member of the early Eocene fauna of China (Li and Ting, 1983; Ting, 1998; Bowen et al., 2002), but no further evidence has been provided to clarify the biostratigraphic occurrence of *A. dubius*. The discovery of *A. zhaii* associated with some Bumbanian forms provides indirect but favorable information supporting the early Eocene occurrence of *A. dubius*.

Some mammals from the *Gomphos*-bearing bed also have significance for intercontinental correlation, which in turn helps the age estimation of the bed. For instance, the newly described euprimate, *Baataromomys ulaanus*, is closely related to *B. brandti* (= *Teilhardina brandti*) from the basal Wasatchian (Wa-0) of Wyoming (Ni et al., 2007). Moreover, preliminary paleomagnetic results show that the *Gomphos*-bearing bed occurs within Chron C24r of the Geomagnetic Polarity Timescale (Bowen et al., 2005), which is consistent with an early Eocene age for the *Gomphos*-bearing bed in the upper Nomogen Formation, as is also suggested by biostratigraphic correlation.

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