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内蒙古二连盆地早古近纪中兽科（哺乳动物纲）新材料[1)]

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摘要：描述了近年来发现于内蒙古二连盆地东部呼和勃尔和地区以及巴彦乌兰早古近纪地层中的中兽科化石材料，共计4属6种，包括一个未定种和发现于阿山头组底部的努和廷中兽新种（*Mesonyx nuhetingensis* sp. nov.）。新种区别于该属其他种的特点是：p4为最长下颊齿以及p3和p4舌侧有弱的齿带。其余属种包括：*Dissacus serratus*，*Dissacus* sp.，*Mesonyx uqbulakensis*，*Mongolonyx dolichognathus* 和 *Harpagolestes leei*。总结了该地区中兽演化的总体趋势：体形逐渐大型化，取食习惯从主动捕猎逐渐转向食用腐尸及骨骸。

关键词：内蒙古二连盆地，古近纪，中兽科，演化趋势

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NEW MESONYCHID (MAMMALIA) MATERIAL FROM THE LOWER PALEOGENE OF THE ERLIAN BASIN, NEI MONGOL, CHINA

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Abstract Early Paleogene mesonychid specimens, recently collected from the Huheboerhe area and Bayan Ulan, eastern Erlian Basin, Nei Mongol (Inner Mongolia), are described in this paper. They represent six species and four genera, a few of the specimens are specifically indeterminate. *Mesonyx nuhetingensis* sp. nov., from the basal Arshanto Formation, differs from previously known species of *Mesonyx* in p4 being the longest lower cheek tooth and weak lingual cingula being present on p3 and p4, respectively. Other mesonychid specimens described in this paper are referred to *Dissacus serratus*, *Dissacus* sp., *Mesonyx uqbulakensis*, *Mongolonyx dolichognathus* and *Harpagolestes leei*. General evolutionary trends seen in mesonychids from the Erlian Basin show a gradual increase in body size and a change in feeding habits from active predation to scavenging.

Key words Erlian Basin, Nei Mongol; Paleogene; Mesonychidae; evolutionary trends

1 Introduction

Mesonychia is a mammalian group known from Paleogene terrestrial deposits of Europe, North America and Asia, and is now considered monophyletic with a basal split between the

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Hapalodectidae and Mesonychidae(O'Leary, 1998; Spaulding et al., 2009). Phylogenetic resolution within Mesonychidae is limited(O'Leary and Gatesy, 2008; Spaulding et al., 2009). Mesonychia has historically been associated with the origin of Cetacea(Van Valen, 1966; Zhou et al., 1995; Geisler and Luo, 1998; O'Leary, 1998; Luo and Gingerich, 1999; O'Leary and Gatesy, 2008). However, recent phylogenetic analyses have not recovered this result in the most parsimonious trees. The group now is considered to be more or less closely related to ungulates(Spaulding et al., 2009).

This paper reports some fragmentary mesonychid specimens from the Upper Paleocene through Middle Eocene of the eastern Erlian Basin, Nei Mongol (Fig. 1, shading). The specimens are referable to various species, including a new one. Resolving mesonychid interrelationships is beyond the scope of this paper. So far, however, no one has studied the succession of ecological niches occupied by mesonychians at different stratigraphic levels, although Szalay and Gould(1966) identified five adaptive "levels" within Mesonychia based on feeding and locomotor adaptations. The specimens described in this paper provide an opportunity for such a study for mesonychids because comprehensive and accurate geologic information is available for each specimen. Furthermore, the stratigraphic age, subdivisions and correlation within the eastern Erlian Basin have been clarified by previous studies(Meng et al., 2007; Sun et al., 2009; Wang et al., 2010).

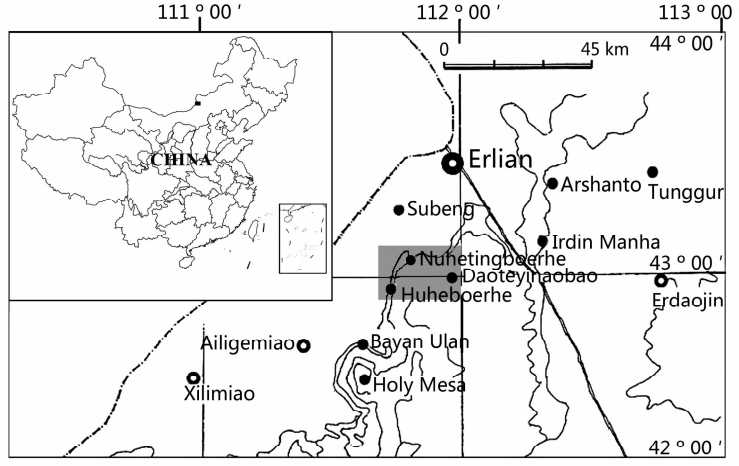

Fig. 1 Fossil localities(black dots) in the Erlian Basin, Nei Mongol
Shading indicates the location of the Huheboerhe area

The specimens described in this paper are housed in the Institute of Vertebrate Paleontology and Paleoanthropology(IVPP), Beijing. Abbreviations: AMNH, American Museum of Natural History, New York; CM, Carnegie Museum of Natural History, Pittsburgh; MAE-BU, Mongolian Academy of Sciences and American Museum of Natural History Joint Expedition-Bumban; YPM-PU, Yale Peabody Museum of Natural History, Princeton University Collection, New Haven; UM, University of Michigan Museum of Paleontology, Ann Arbor; USNM, National Museum of Natural History, Smithsonian Institution, Washington D. C.

2 Systematic paleontology

Order Mesonychia Matthew, 1937
Family Mesonychidae Cope, 1875
Genus *Dissacus* Cope, 1881
***Dissacus serratus*(Chow & Qi, 1978)**
(Fig. 2)

1978 *Plagiocristodon serratus* Chow and Qi, p. 77
1978 ? *Dissacus* sp. Chow and Qi, p. 77
1998 *Dissacus serratus* Meng et al., p. 148

Specimens IVPP V 15914, a left M1; V 15915, two right mandible fragments from a single individual, one with lower canine, p2-p4 and alveolus for p1 (V 15915-1), and the other with m2-m3 (V 15915-2).

Locality and horizon Bayan Ulan; lower Nomogen Formation (NM-1), Late Paleocene, Gashatan.

Supplementary diagnosis Hypocone and metaconule both vestigial, but distinct on M1.

Description M1 is nearly complete except for damage at the posterolabial portion. The damaged portion probably corresponds to the metastyle shelf. Among the three main cusps, the paracone is the highest, and the metacone is higher than the protocone. The parastyle is low. The metaconule and hypocone are both vestigial, but distinct (Fig. 2A). The mandibular symphysis extends posteriorly to the level of p3. The depth of the mandible below p2 to p4 is consistent. Two mental foramina appear on the mandible, the anterior one below p2 and the posterior one below p3 (Fig. 2B). The enamel-dentine line on the lower canine is oblique, being lower on the labial side than on the lingual side. The p2 has a large protoconid with well developed anterior and posterior carinae, but no paraconid. Posterior to the protoconid is a moderate-sized talonid with anterior and posterior crests. The protoconid of p3 has an extreme posterior curvature, with knife-edged anterior and posterior carinae. Anterolingual to the anterior carina is a small paraconid. The posterior carina terminates in a carnassial notch. The hypolophid stretches from the carnassial notch to the hypoconid. The talonid is subequal to the trigonid in width. The p4 is larger than p3, with a proportionally larger paraconid and longer talonid, but p4 resembles p3 in other features (Fig. 2B). The protoconid of m2 is larger and taller than the anterolingually situated metaconid. A small trigonid basin is encircled by the protoconid, metaconid and paraconid. The paraconid is low and small. The hypolophid of m2 is more convex than that of p4. The m3 is distinctly smaller than m2. Its trigonid basin is less well developed than that of m2 (Fig. 2C).

Discussion Holotype of *D. serratus*, IVPP V 5480, is a fragmentary mandible with broken p2, complete p3-4, and broken m1. The specimen was recorded by Chow and Qi (1978) as the holotype and the only included specimen of *Plagiocristodon serratus*. Meng et al. (1998) re-examed it and recognized as the holotype of *D. serratus*, new combination. Although because of some reasons I can not observe the specimen, the plate is available. The character, sharp and canted trigonid, of p3 and p4 in V 15915-1 is same as that of the holotype. Height and length of the two teeth are also similar to V 5480's. Except for p4, m2 and m3 are relatively smaller in the new specimens (Table 1) than in the IVPP V 11147, the characters of m2 and m3 in the new specimens all match those seen in material previously referred to *D. serratus* (V 5478 and V 11147). However, there are also some potentially diagnostic differences between the new specimens and the description of *D. serratus* given by Meng et al. (1998). In the new specimens,

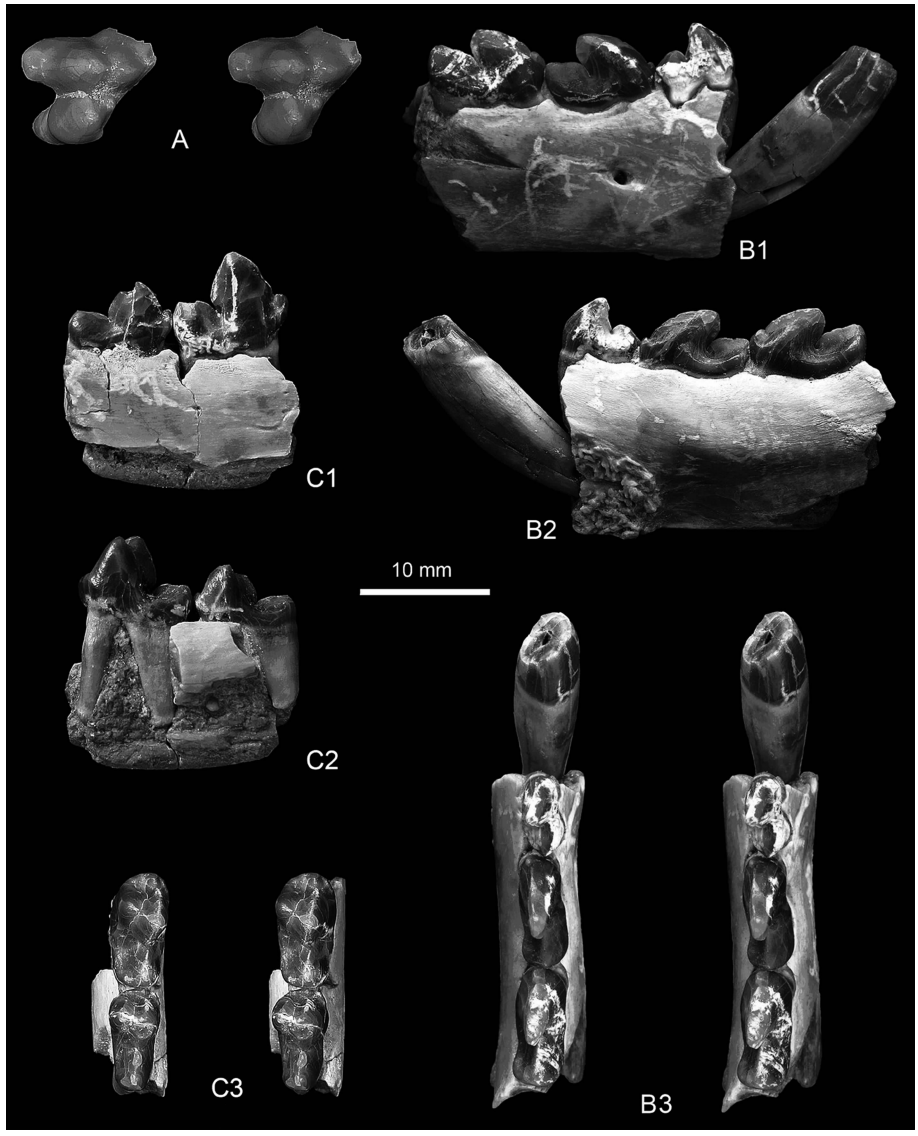

Fig. 2 *Dissacus serratus* from lower Nomogen Formation of eastern Erlian Basin
A. IVPP V 15914, left M1; B. V 15915-1, part of right mandible with c, p2-p4; C. V 15915-2, another part of right mandible with m2-m3; A, B3 and C3 are stereographs, in occlusal view; B1 and C1 in labial view; B2 and C2 in lingual view

M1 has a metaconule and hypocone (Meng et al. (1998) stated that "there is no hypocone or conules"), a p1 is present, and p2 is double-rooted rather than single-rooted. Reexamination of the fragmentary left upper and lower jaw of V 11147, a specimen previously described by Meng et al. (1998), makes it possible to correct some inaccuracies in their description. First, M1 of *D. serratus* actually has a hypocone, and is worn in such a way that it cannot be determined whether or not a metaconule was originally present. Second, a single-rooted p1 does exist in the mandible, situated labial to p2. Finally, p2 is double-rooted. Accordingly, there are no genuinely diagnostic differences between the new specimens from Bayan Ulan and the established morphology of *D. serratus*, and the new specimens should be referred to this taxon.

Table 1　Dental measurements of *Dissacus serratus*　(mm)

Specimen number	M1		c		p2		p3		p4		m2		m3	
	L	W	L	W	L	W	L	W	L	W	L	W	L	W
V 15914	10.6	9.7	—	—	—	—	—	—	—	—	—	—	—	—
V 15915-1 ~2	—	—	6.07	4.39	6.2	3.01	8.95	3.80	9.5	4	9.5	4.9	8.3	4.15
V 11147	9.27	9.55	—	—	—	—	8.8	3.72	11.1	3.82	11	5	9.33	4.27

Note: L. length; W. width.

Dissacus sp.

(Fig. 3)

Specimens　IVPP V 15916, labial half of a right M2; V 15917, a broken right M1 missing the metacone and metastyle; V 15918, posterior 2/3 of a right m1.

Localities and horizon　Wulanboerhe (V 15916) and Nuhetingboerhe (V 15917, V 15918); upper Nomogen Formation (NM-3), earliest Eocene, Bumbanian.

Description　The posterolabial part of M1 is missing. The paracone and protocone of this tooth are subequal in size, although the former is slightly taller than the latter. The parastyle is low, with a convex labial portion. The trigon basin opens posteroventrally, and is bounded by pre-and postprotocristae (Fig. 3B). Only the labial cusps are preserved on M2. The metacone of this tooth is isolated of and lower than the paracone. The parastyle is low and wide. The metastyle is cingulum-form (Fig. 3A). The m1 has a labially situated hypolophid and a distinct entoconid. Breakage of the tooth allows the pulp cavity to be easily observed. A distinct sulcus separates the protoconid and metaconid apart completely (Fig. 3C1). This contrasts with the general impression that the metaconid and protoconid are largely confluent except near their apices.

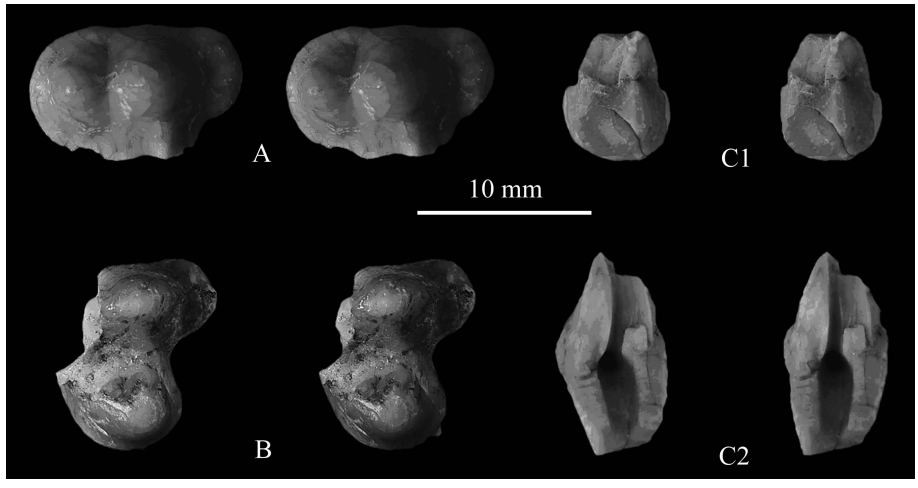

Fig. 3　*Dissacus* sp. (stereographs) from upper Nomogen Formation of eastern Erlian Basin
A. IVPP V 15916, right M2; B. V 15917, right M1; C. V 15918, broken right m1 preserving the rear parts of the trigonid and talonid; A, B and C1 in occlusal view; C2 in ventral view

Discussion　The specimens, V 15916-15918, represent small mesonychid species and the upper molar, V 15916 has an isolated metacone. It is most likely these specimens can be assigned to *Dissacus*. So far, three species of *Dissacus*, namely *D. zengi* (Ting et al., 2004), *D. bohaiensis* (Tong and Wang, 2006) and *D. zanabazari* (Geisler and McKenna,

2007), have been recorded in Bumbanian faunas. The new specimens differ from *D. zengi* in having a well developed parastyle and metastyle on the upper molar, wider lower molar and distinctly larger tooth size. The new specimens are close in size to *D. zanabazari* (Table 2), but differ from the latter in that M1 lacks a small basin (fig. 3 of Geisler and McKenna, 2007) and in that the paracone of M2 is less than twice as high as the metacone. All specimens that have been assigned to *D. bohaiensis* are lower jaws and teeth, and V 15918 clearly differs from the lower molar of *D. bohaiensis* in being distinctly wider and in having an entoconid (Table 2). The new specimens are distinguishable from all the previously described Bumbanian species of *Dissacus*, but are so fragmentary that I do not consider it advisable to erect a new species.

Table 2 Dental measurements of Bumbanian *Dissacus* specimens (mm)

Taxon	Specimen number	M1				M2				m1			
		L		W		L		W		L		W	
		l	r	l	r	l	r	l	r	l	r	l	r
Dissacus sp.					10.7		12.2						5.8*
D. zengi	IVPP V 13040	—	—	—	—	8.6	—	7.7	—	—	—	—	—
D. bohaiensis	IVPP V 10729	—	—	—	—	—	—	—	—	10.75	—	4.8	—
D. zanabazari	MAE-BU-97-13786	—	12.1	—	10	9.8	10.4	10.6	10.8	12	10.7	5.4	4.6

* width of talonid; L. length; W. width; l. left; r. right.

Genus *Mesonyx* Cope, 1872

Mesonyx uqbulakensis (Tong, 1989)

(Fig. 4)

Specimen IVPP V 15919, a broken right mandible containing p4 and m1.

Locality and horizon Wulanboerhe; basal Arshanto Formation (AS-1), Early Eocene, Arshantan.

Supplementary diagnosis Comparing with the type species and the *M. nuhetingensis* sp. nov., *M. uqbulakensis* is more than 10% smaller in tooth's length, and has more lingually situated entoconid and well developed entolophid on m1.

Description The p4 has a small, lingually situated paraconid and a retroflexed protoconid. The talonid of this tooth has a midline situated hypolophid. On p4 the anterior end of the protoconid and the posterior end of the talonid have both clearly been abraded by the upper teeth. The m1 has an anteriorly inclined paraconid and a retroflexed protoconid. This tooth bears a distinct talonid basin, which is encircled by hypolophid and well developed entolophid (Fig. 4A3). The entoconid is the most lingually situated cusp of the tooth, which makes the entolophid look distinctly elongated.

Discussion The teeth of V 15919 are moderate in size, transversely compressed and low-crowned. The m1 has no metaconid. These characters are congruent with those of *Mesonyx*. The type specimen of *M. uqbulakensis*, V 7922, is a broken upper jaw containing P4-M2 and alveoli of P2, P3 and M3, which can not be used to compare with the V 15919. V 7922.4, identified as a lower premolar, is one of the included specimens of *M. uqbulakensis* from the same locality where V 7922 was found (Tong, 1989). This specimen represents an old individual, with the paraconid completely worn down. The tooth has a distinctly lingually situated entoconid and a well developed entolophid. These features can also be observed on m1 of V 15919, but have not been observed in other species of *Mesonyx*. The measurements of V 7922.4 are similar to those

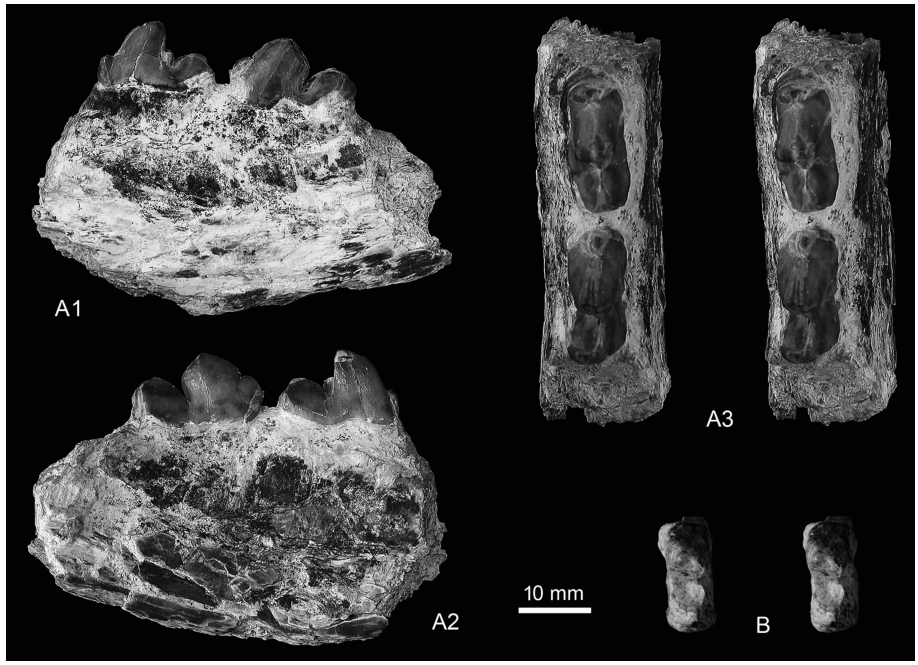

Fig. 4　*Mesonyx uqbulakensis* from basal Arshanto Formation of eastern Erlian Basin
A. IVPP V 15919, broken right mandible with p4 – m1; B. V 7922 – 4, right m1; A1 in lingual view; A2 in labial view; A3 and B in occlusal view, stereographs

of m1 of V 15919(Table 3). Accordingly, V 15919 should be referred to *M. uqbulakensis*, and V 7922.4 can be identified as an m1.

This species was originally named *M.* "*üqbulakensis*" by Tong(1989). However, article 32.5 of the International Code of Zoological Nomenclature requires that the name be amended to *M. uqbulakensis*, and the latter spelling is used in this paper.

Table 3　Dental measurements of *Mesonyx*　(mm)

Taxon	Specimen number	P3		p3		p4		m1		m2		m3	
		L	W	L	W	L	W	L	W	L	W	L	W
M. nuhetingensis	V15920-1 ~ 3	15.2	8.6	19.7	8.9	22.2	9.5	20.3	9	19.4	8.7	13.7	8
	V15919	—	—	—	—	16	7.6	17.8	7.6	—	—	—	—
M. uqbulakensis	V7922.2	—	—	—	—	—	—	16.5	7.2	—	—	—	—
	V7922.4	—	—	—	—	—	—	15.5	7.6	—	—	—	—
M. obtusidens	PU 10308	16	8	16.8	7.5	19.3	8.4	19.8	8.8	18	8	14	7

Note: L. length, W. width.

Mesonyx nuhetingensis sp. nov.

(Fig. 5)

Holotype　IVPP V 15920, fragments from same individual, including a left P3(V 15920-1), a right mandible with p4-m3(V 15920-2)and a right p3(V 15920-3).

Hypodigm　Holotype only.

Type locality and horizon　Nuhetingboerhe; basal Arshanto Formation(AS-1), Early

Eocene, Arshantan.

Etymology The species name refers to the type locality, Nuhetingboerhe.

Diagnosis The p4 is the longest lower cheek tooth, whereas in *M. obtusidens* and *M. uqbulakensis* m1 is longer than p4 (Table 3). A weak lingual cingulum exists in both p3 and p4.

Description P3 (V 15920-1) is double-rooted. Its upper part of the paracone is missing. The anterior wear facet of the tooth is smoothly curved with an anteriorly projecting basal portion, implying that the tooth may have a parastyle. In occlusal view, the vertical plane of the paracone faces posterolabially, whereas that of the metastyle faces anterolabially (Fig. 5). The metastyle is well developed, with a trenchant edge. There is no hypocone on the lingual shelf.

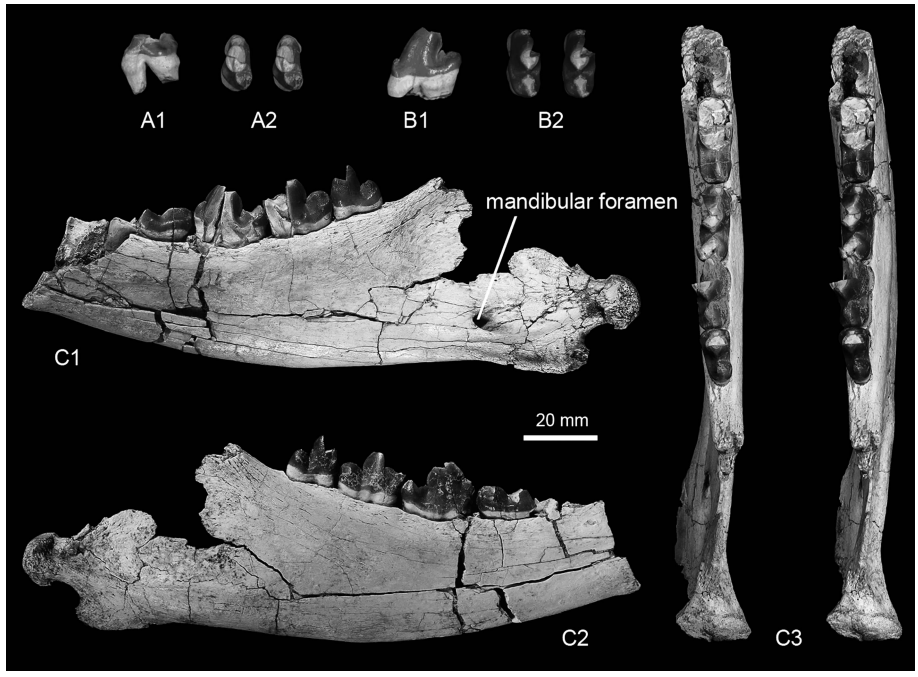

Fig. 5 *Mesonyx nuhetingensis* sp. nov. from basal Arshanto Formation of eastern Erlian Basin
A. IVPP V 15920-1, left P3; B. V 15920-3, right p3; C. V 15920-2, right mandible with talonid of p4 and m1-m3; A1, B1 and C1 in lingual view; A2, B2 and C3 in occlusal view; C2 in lateral view; A2, B2 and C3 are stereographs

The mandible is missing the part anterior to p3 and the posterior part of the ascending ramus. A small mental foramen lies ventral to p3. The masseteric fossa is shallow and extensive. The condyle is moderate in size, with a short neck, and lies below the level of the tooth row. The mandibular foramen is large and deep. The angle of the mandible is well developed and distinctly inflected.

In occlusal view, the profile of p3 is an elongated ellipse. The tooth is dominated by a large, retroflexed protoconid that has anterior and posterior carinae. The posterior carina is better developed than the anterior one. At the base of the anterior carina is a small paraconid. The posterior carina terminates in a carnassial notch. A vestigial lingual cingulum is present on the tooth.

The p4 is distinctly the longest cheek tooth (Table 3), and has a rectangular occlusal profile. The trigonid of p4 is badly damaged. Compared to all of the other cheek teeth in the mandible, p4 has a longer and more prominently ridged talonid. A hypolophid is situated along the

midline of the tooth. The lingual cingulum is weak, but still better developed than its counterpart on p3.

Molar size decreases from m1 to m3. Most of the lingual side of m1 is missing. The m1 has a well developed and anteriorly inclined paraconid, and a low protoconid with distinct anterior and posterior carinae. Posterior to the posterior carina is a vestigial carnassial notch. On m2 the anterolingual part of the trigonid is not preserved. Compared with m1, m2 has a higher protoconid and a higher and anteroposteriorly compressed paraconid. The anterior part of the protoconid of m3 is partly missing. Losing M3 is one of the evolutionary trends of mesonychid. No any abrasion marks on m3 in V 15920-2 implies that the animal lacked a M3. The paraconid, protoconid and talonid of m3 are all distinctly shorter than those of m1 and m2, and the talonid is transversely narrower than the trigonid.

Discussion Like other species of *Mesonyx*, the new species can easily be distinguished from other mesonychid genera based on its moderately sized and transversely compressed lower teeth, as well as the shallowness of the horizontal ramus of the mandible and the absence of M3. The new species differs from *M. obtusidens* (Scott, 1888) in that p4 is the longest cheek tooth, and in that vestigial lingual cingula are present on p3 and p4.

Differences between *M. uqbulakensis* and the new species being attributed to sexual dimorphism or interspicific difference should be taken into account, because the two species are both recovered from the same mammal-bearing horizon. O'leary et al. (2000) had addressed the problem of sexual dimorphism of *Ankalagon*, the largest Paleocene mesonychid in North America. Based on comparisons with extant taxa, they conclude that large differences in canine size and dentary depth and small differences in premolar and molar dimensions between the New Mexico Museum of Natural History (NMMNH) P-16309 and the holotype of *Ankalagon* suggest that *Ankalagon* is sexually dimorphic. However, canine and relatively complete mandible material of *M. uqbulakensis* and the canine material of new species have not ever been recovered. Ratios of linear dental measurements of the two species are the only data available. The data (Table 4) show that differences in p4 and m1 dimensions of the two species are distinctly larger than those of *Ankalagon*. Besides distinctly larger dental linear differences, there are some other differences between *M. uqbulakensis* and the new species: the p4 being longer than m1, the presence of lingual cingula on p3 and p4 and less well developed entoconid and entolophid, which show that they are two isolated species and not sexual dimorphism.

Table 4　Ratios of linear dental measurements of p4 and m1 for *Ankalagon* (O'leary et al., 2000) and *Mesonyx*

Ratios	p4 L	p4 W	m1 L	m1 W
Ankalagon	1.15	1.13	1.02	1.09
Mesonyx	1.39	1.25	1.15 (1.23 and 1.30)	1.18 (1.25 and 1.18)

Note: for *Mesonyx*, ratios are dimensions of V 15920-2 (holotpe)/V 15919 (V 7922.2 and V 7922.4); L. length; W. width.

Genus *Mongolonyx* Szalay & Gould, 1966

Mongolonyx dolichognathus Szalay & Gould, 1966

(Fig. 6)

Specimen IVPP V 15938, a right P4.

Locality and horizon Nuhetingboerhe; middle Arshanto Formation (AS-2), Early Eocene, Arshantan.

Description V 15938 is a large broken right upper cheek tooth (Fig. 6). Its paracone and protocone are both blunt, but the former is taller than the latter. The anterior part of the

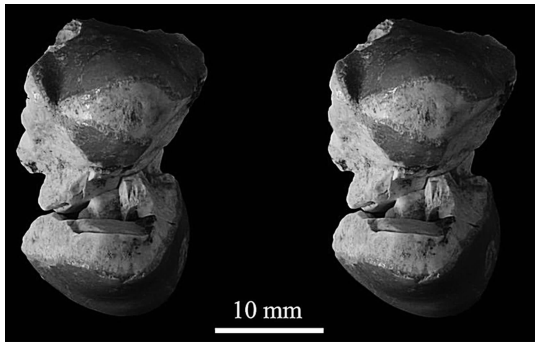

Fig. 6 right P4 of *Mongolonyx dolichognathus*, IVPP V 15938, in occlusal view, stereographs

tooth is distinctly more heavily eroded than the posterior part. The metacone and parastyle are both distinct, and moderate in size. The anterolingual part of the base of the protocone is swollen, forming a vestigial shelf. The width of the tooth is 29.1 mm.

Discussion V 15938 is a broken tooth, its occlusial outline and the size are quite similar to that of P4 in AMNH 26662, a left maxilla with P2-M2 of *M. dolichognathus* (Szalay and Gould, 1966). According to the latest stratigraphic correlations within the eastern Erlian Basin (Meng et al., 2007; Wang et al., 2010), the strata that produced AMNH 26662 and V 15938 are both referable to the Arshanto Formation. So I tentatively refer V 15938 as a right P4 to *M. dolichognathus*.

Genus *Harpagolestes* Wortman, 1901
Harpagolestes leei Jin, 2005
(Fig. 7)

Specimen IVPP V 15921, a right P4; V 17617, a complete left P2; V 17618, talonid of left cheek tooth; V 17619, anterior part of trigonid of right m1; V 17620, talonid of left cheek tooth.

Locality and horizon Huheboerhe (V 15921, V 17617 and V 17618) and Daoteyin Obo (V 17619 and V 17620); basal Irdin Manha Formation (IM-1), Middle Eocene, Irdinmanhan.

Supplementary diagnosis The P4 has a well developed preprotocrista, and is wider than long.

Description The P2 is robust with a blunt paracone, but no parastyle. The metastyle is low, and bears a ventrolingually facing wear facet. The lingual shelf is vestigial (Fig. 7B). Measurement (in mm): length 22.1, width 13.3.

The metastyle shelf of P4 is missing. The paracone and protocone are both tall and blunt, and the former is taller than the later. The parastyle is low, and anteroposteriorly compressed. The tooth has a preprotocrista, but no postprotocrista. At the base of the protocone, a weak shelf encircles the cusp (Fig. 7A). Measurement (in mm): length 23.7, width 25.2.

V17618-17620 represent broken lower cheek teeth from large mesonyc-hids.

Discussion V 15921 is similar in

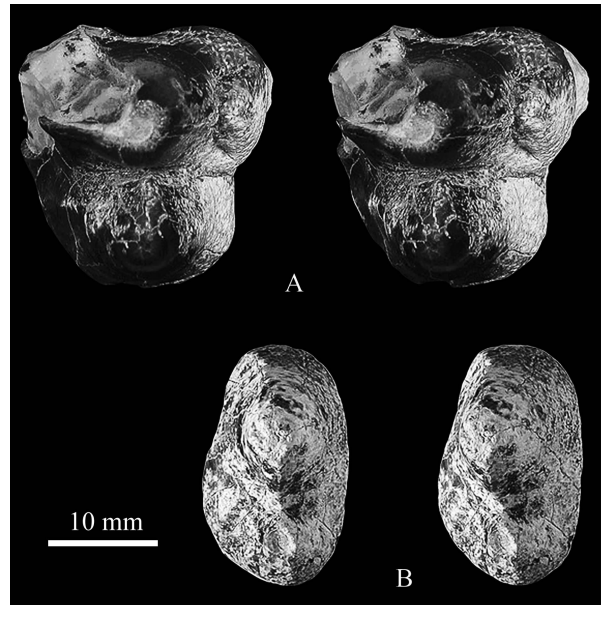

Fig. 7 *Harpagolestes leei* from basal Irdin Manha Formation of eastern Erlian Basin
A. IVPP V 15921, right P4; B. V 17617, left P2; in stereographs

both measurements and general morphological features to P4 of *H. leei* (Jin, 2005) from Lushi Basin, Henan. Accordingly, V 15921 can be unproblematically referred to *H. leei*. Assignment of the P2 and lower cheek teeth from the present sample to this species is less certain. However, they are proportionate in size to the upper cheek teeth of *H. leei*, and *H. leei* is the only mesonychid species known from the Irdin Manha Formation. Therefore, all of these specimens are probably referable to *H. leei*.

3　Evolutionary trends in the Mesonychidae from Erlian Basin

The mesonychid specimens described in this paper were recently collected from the Huheboerhe area and Bayan Ulan, eastern Erlian Basin, with comprehensive and accurate stratigraphic information available in each case. During the last few years, significant progress has been made in clarifying the stratigraphy of the Erlian Basin, particularly in the Huheboerhe area. Paleogene strata in the region encompass three lithological units: the Nomogen, Arshanto and Irdin Manha formations. The sequence contains faunas from four Asian land mammal ages, the Gashatan, Bumbanian, Arshantan, and Irdinmanhan, which together extend from the beginning of Late Paleocene through the middle Middle Eocene. At least 12 mammal-bearing horizons have been recognized in these strata, including 4 in the Nomogen Formation, 6 in the Arshanto Formation, and 2 in the Irdin Manha Formation. These horizons are labeled in ascending order as NM-1 to NM-4, AS-1 to AS-6, and IM-1 to IM-2 (Fig. 8). The so-called Houldjin gravels of the CAE from this area mostly belong to the Irdin Manha Formation, while the "Irdin Manha beds" of the CAE belong to the Arshanto Formation. The fossil assemblage of the Nomogen Formation in the Bayan Ulan area generally correlates with the NM-1 (Meng et al., 2004, 2007; Bai, 2006; Ni et al., 2007; Sun et al., 2009; Wang et al., 2008, 2010). The distribution of mesonychids within the strata in the Huheboerhe area and Bayan Ulan can be summarized as follows. The Nomogen Formation contains *D. serratus*, from NM-1, of Gashatan age and *Dissacus* sp., from NM-3, of Bumbanian age. The Arshanto Formation is mostly Early Eocene in age, and *Mesonyx uqbulakensis*, *M. nuhetingensis* and *Mongolonyx dolichognathus* all come from the Early Eocene part of the formation. However, the horizon of *Mesonyx* (AS-1) is lower than that of *M. dolichognathus* (AS-2). Finally, *H. leei* is the only species recovered from the Irdin Manha Formation (Fig. 8).

Szalay and Gould (1966) identified five adaptive "levels", or rather ecological niches, occupied by particular mesonychids. However, their "omnivore level" was occupied only by *Andrewsarchus*, whose subsequent removal from Mesonychia (McKenna and Bell, 1997) reduced the number of mesonychid ecological niches in this scheme to four. A succession of mesonychid ecological niches is clearly evident in the Erlian Basin. In the Gashantan and Bumbanian, the mesonychids of the basin (*D. serratus* and *Dissacus* sp.) occupied the carnivore niche only. The linear dental measurements of *Dissacus* sp. are distinctly larger than those of *D. serratus*. The mesonychid of the early part of the Arshantan (*Mesonyx*) occupied the advanced carnivore niche, being larger, more powerful and capable of running faster. From the middle part of the Arshantan onwards, the mesonychids inhabiting the basin were large bone-crushing animals (*M. dolichognathus* and *H. leei*). *Pachyaena* sp. (Meng et al., 1998), assigned to "omnivore-carnivore level" by Szalay and Gould (1966), is not included in this account of mesonychid ecology changing in the Erlian Basin because Meng et al. (1998) were unsure of the presence of this genus in the Bayan Ulan Fauna. Accordingly, the general evolutionary trends seen in mesonychids from the Late Paleocene through the Middle Eocene in the Erlian Basin can be described as a gradual increase in body size and an increase in predatory capability (e. g. from *Dissacus* to *Mesonyx*) followed by a shift to bone-crushing and presumably scavenging (e. g. from *Mesonyx* to the later genera).

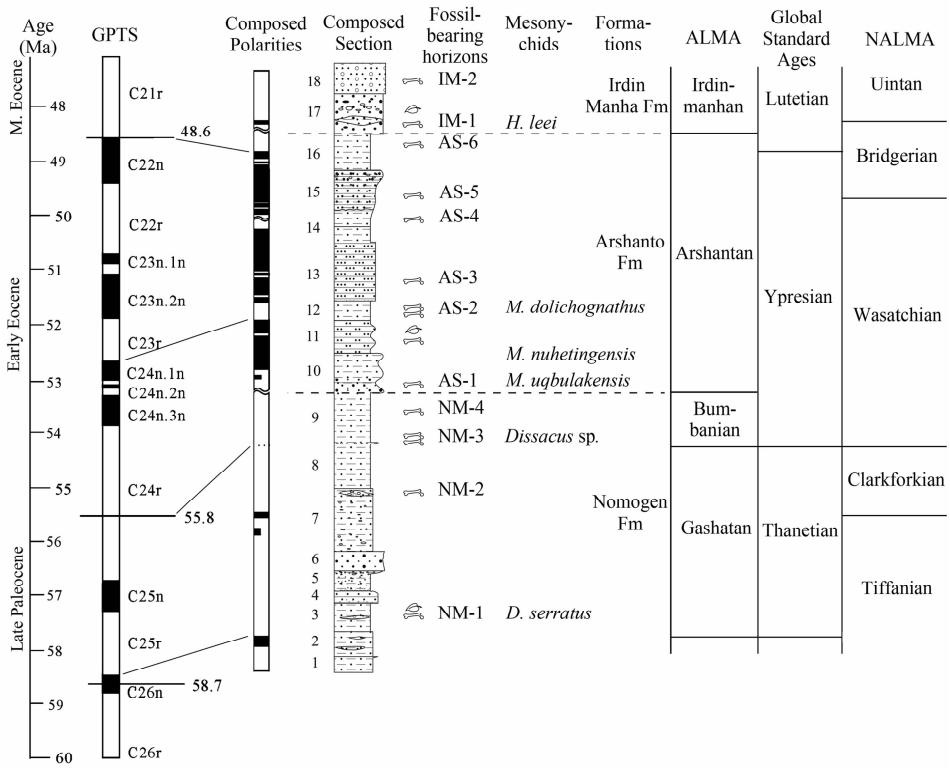

Fig. 8 Paleogene stratigraphy, paleomagnetic polarities, mammalian horizons, mesonychid taxa and their correlation in the eastern Erlian Basin, with geological age assignments, modified from Wang et al. (2010)

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References

Bai B(白滨), 2006. New material of Eocene Dinocerata(Mammalia) from the Erlian Basin, Nei Mongol(Inner Mongolia). Vert PalAsiat(古脊椎动物学报), **44**(3): 250–261(in Chinese with English summary)

Chow M C(周明镇), Qi T(齐陶), 1978. Paleocene mammalian fossils from Nomogen Formation of Inner Mongolia. Vert PalAsiat(古脊椎动物学报), **16**(2): 77–85(in Chinese with English summary)

Geisler J H, Luo Z X, 1998. Relationships of Cetacea to terrestrial ungulates and the evolution of cranial vasculature in Cete. In: Thewissen J G ed. The Emergence of Whales. New York: Plenum. 163–212

Geisler J H, McKenna M C, 2007. A new species of mesonychian mammal from the Lower Eocene of Mongolia and its phylogenetic relationships. Acta Palaeont Pol, **52**(1): 189–212

Jin X(金迅), 2005. Mesonychids from Lushi Basin, Henan Province, China. Vert PalAsiat(古脊椎动物学报), **43**(2):

151 – 164(in Chinese with English summary)

Luo Z X, Gingerich P D, 1999. Terrestrial Mesonychia to aquatic Cetacea: transformation of the basicranium and evolution of hearing in whales. Univ Mich Pap Paleont, **31**: 1 – 98

McKenna M C, Bell S K, 1997. Classification of Mammals Above the Species Level. New York: Columbia University Press. 1 – 631

Meng J, Bowen G J, Ye J et al., 2004. *Gomphos elkema* (Glires, Mammalia) from the Erlian Basin: evidence for the early Tertiary Bumbanian land mammal age in Nei-Mongol, China. Am Mus Novit, (3425): 1 – 24

Meng J, Wang Y Q, Ni X J et al., 2007. New stratigraphic data from the Erlian Basin: implications for the division, correlation, and definition of Paleogene lithological units in Nei Mongol(Inner Mongolia). Am Mus Novit, (3570): 1 – 31

Meng J, Zhai R J, Wyss A R, 1998. The Late Paleocene Bayan Ulan Fauna of Inner Mongolia, China. Bull Carnegie Mus Nat Hist, **34**: 148 – 185

Ni X J, Beard K C, Meng J et al., 2007. Discovery of the first early Cenozoic euprimate(Mammalia) from Inner Mongolia. Am Mus Novit, (3571): 1 – 11

O'Leary M A, 1998. Phylogenetic and morphometric reassessment of the dental evidence for a mesonychian and cetacean clade. In: Thewissen J G ed. The Emergence of Whales. New York: Plenum. 133 – 161

O'Leary M A, Gatesy J, 2008. Impact of increased character sampling on the phylogeny of Cetartiodactyla(Mammalia): combined analysis including fossils. Cladistics, **24**(4): 397 – 442

O'Leary M A, Lucas S G, Williamson T E, 2000. A new specimen of *Ankalagon*(Mammalia, Mesonychia) and evidence of sexual dimorphism in mesonychians. J Vert Paleont, **20**(2): 387 – 393

O'Leary M A, Rose K D, 1995. Postcranial skeleton of the Early Eocene mesonychid *Pachyaena*(Mammalia, Mesonychia). J Vert Paleont, **15**(2): 401 – 430

Scott W B, 1888. On some new and little known creodonts. J Acad Nat Sci Phila, **9**: 155 – 185

Spaulding M, O'Leary M A, Gatesy J et al., 2009. Relationships of Cetacea(Artiodactyla) among mammals: increased taxon sampling alters interpretations of key fossils and character evolution. PLoS One, **4**(9): 1 – 14

Sun B(孙勃), Yue L P(岳乐平), Wang Y Q(王元青)et al., 2009. Magnetostratigraphy of the early Paleogene in the Erlian Basin. J Stratigr(地层学杂志), **33**(1): 62 – 68(in Chinese with English abstract)

Szalay F S, Gould S J, 1966. Asiatic Mesonychidae(Mammalia, Condylarthra). Bull Am Mus Nat Hist, **132**: 129 – 173

Tong Y S(童永生), 1989. Some Eocene mammals from the Üqbulak area of the Junggar Basin, Xinjiang. Vert PalAsiat(古脊椎动物学报), **27**(3): 182 – 196(in Chinese with English summary)

Tong Y S(童永生), Wang J W(王景文), 2006. Fossil mammals from the Early Eocene Wutu Formation of Shandong Province. Palaeont Sin(中国古生物志), New Ser C, **28**: 1 – 206(in Chinese with English summary)

Ting S Y, Wang Y Q, Schiebout J A et al., 2004. New Early Eocene mammalian fossils from the Hengyang Basin, Hunan, China. Bull Carnegie Mus Nat Hist, **36**(1): 291 – 301

Van Valen L M, 1966. The Deltatheridia, a new order of mammals. Bull Am Mus Nat Hist, **132**: 1 – 126

Wang Y Q, Meng J, Beard K C et al., 2010. Early Paleogene stratigraphic sequences, mammalian evolution and its response to environmental changes in Erlian Basin, Inner Mongolia, China. Sci China Earth Sci, **53**(12): 1918 – 1926

Wang Y Q, Meng J, Ni X J et al., 2008. A new Early Eocene arctostylopid(Arctostylopida, Mammalia) from the Erlian Basin, Nei Mongol(Inner Mongolia), China. J Vert Paleont, **28**(2): 553 – 558

Zhou X Y, 1995. Evolution of Paleocene-Eocene Mesonychidae (Mammalia, Mesonychia). PhD dissertation. Ann Arbor: University of Michigan. 1 – 402