Quaternary International 347 (2014) 139–147

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Late Pleistocene mammalian fauna from Wulanmulan Paleolithic Site, Nei Mongol, China

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ARTICLE INFO

Article history:
Available online 22 June 2014

Keywords:
Late Pleistocene
Mammalian fauna
Paleolithic
Ordos
Nei Mongol
North China

ABSTRACT

Discovered in 2010 with the construction of Landscape Park on the left bank of Wulanmulun River in Kangbashi District of Nei Mongol, Wulanmulun Paleolithic Site yielded large quantities of mammalian specimens during 2010–2012 rescue excavations. Identified fossil materials include *Myospalax* sp., *Cricetulus* sp., *Microtus* sp., *Apodemus* sp., *Arvicola* sp.?, Dipodidae gen. et sp. indet., *Lepus* sp., Mustelidae gen. et sp. indet., *Coelodonta antiquitatis*, *Equus przewalskii*, *Camelus* cf. *C. knoblochi Megaloceros ordosianus* and *Gazella* sp. The fauna analyses show that the paleoenvironment in Wulanmulun Site area might have been a mixture or mosaic of grassland and forest with some small streams and swamps. The fluctuation of annual temperature might have been high, with the winter very cold and the summer relatively warm. The Wulanmulun fauna is in the same paleozoogeographic sub-province as Baotou, Shiyu, Salawusu and Loufangzi faunas, different from that of the Xiaogushan and Yanjiagang faunas of Northeast China, and more different from that of the Dantu fauna of East China. The Wulanmulun area was suitable for the habitation of the late Paleolithic humans, and Wulanmulun fauna were their main hunting prey.

1. Introduction

Ordos is a region rich in Quaternary deposits and noted for prehistory heritage. The Salawusu (formerly spelled as Sjara-osso-gol) Site and Shuidonggou (previously spelled as Choei-Tong-Keou) Late Paleolithic Site in southern Ordos Plateau discovered by Licent and Teilhard de Chardin (Teilhard de Chardin and Licent, 1924; Boule et al., 1928) are the first noted prehistory sites in Ordos. Many prehistory human specimens and associated mammal fossils were collected from 1922 to 1979, and more than 400 pieces of artifacts were unearthed from 1923 to 1980 at Salawusu site (Wu et al., 1999), and a large amount of artifacts and some mammal fossils were collected from Shuidonggou Site (Boule et al., 1928; Gao et al., 2013). Renewed and expanded excavations at Shuidonggou from 2003 to 2007 yielded a collection of tens of thousands of artifacts (Gao et al., 2008, 2013; Guan et al., 2011). Some mammal fossils were collected around Baotou City in the northern Ordos Plateau in recent decades (Nie and Li, 1988; Huang et al., 1989; Wu et al., 1996; Nie et al., 2008). During the construction of landscape park on both banks of the Wulanmulun River ("Red River" in Mongolian) in Kangbashi District of Ordos Municipality, some fossils were collected from the left bank of the river by an amateur paleontologist in 2010. A trial excavation was conducted soon after by the archaeologists from Ordos Bronze Museum and Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences (IVPP), and a Paleolithic site was discovered in 2010 (Hou et al., 2012). Thousands of pieces of artifacts and mammal bones and some fireplaces have been unearthed since 2010. Here, we report the mammalian fauna associated with Paleolithic artifacts from Wulanmulun Site and try to interpret the paleo-environment of prehistoric Wulanmulun humans based on fauna evidence.

2. Regional setting

The northern part of Ordos Plateau was tectonically active during the middle and late Cenozoic. The east-west Hetao Basin was formed by subsidence of the crust with the upwelling of mantle materials and eruption of basalt around the basin. Several intermittent uplifts and depressions took place and the early and middle

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http://dx.doi.org/10.1016/j.quaint.2014.05.051
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Cenozoic quasi-plains were eroded and cut that resulted complicated topography of the area. The neotectonic movement had been weakened since the Middle Pleistocene and the crust subsided slightly. The lateral erosion of rivers was still active, and formed wide valleys and numerous lakes in the Late Pleistocene. This environment was very favorable for vegetation development and herbivores, as well as for prehistoric human habitation. The crust has been slightly uplifted since the beginning of the Holocene, the vertical erosion of rivers dominated, and the lakes disappeared (Yuan, 1978; Wu et al., 1996). The lacustrine deposits with prehistoric human traces have been exposed, resulting in the discovery of Wulanmulun Paleolithic Site.

Wulanmulun Site (GPS: 39°35′8.90″N; 109°45′39.81″E; 1282 m; see KML file for Google Maps in online supplementary materials) is located on the left bank of the Wulanmulun River in Kangbashi District of Ordos Municipality in Nei Mongol Autonomous Region (Fig. 1). The river originates from a desert near Zhazhaiyinsumo Village of Yikezhao League about 29.4 km northwest of Kangbashi District. It flows into Shaanxi Province, passes Shenmu County, and finally joins the Yellow River at Luoyukouzhen with a total length of about 132.5 km. Some small and ancient tributaries running southward join the Wulanmulun River near the site. They are filled with Quaternary deposits. The total thickness of the deposits measures 15 m. The Paleolithic remains were recovered from the lower part of the deposits with a thickness of 5–8 m. The formation of the deposits can be divided into two periods. The bedrock was cut by a tributary, and a moderate valley formed in the first period. Just after the cutting period the valley started to receive fluvial-lacustrine deposits, including prehistory human traces, in the second period (Hou et al., 2012). The main part of deposits was divided into 8 layers with a total thickness of about 5–8 m (Fig. 2). All layers are composed of sand, silt, or both, and incline slightly eastwards. Archaeological remains were unearthed from Layers 2–8.

The synthesized ^{14}C dating from Layers 1–8 showed that the deposits are older than 30 ka, and OSL (optical stimulated luminescence) dating gave an age from 43 ka to 72 ka. The comprehensive age combining two dating results is from 30 ka to 70 ka (Hou et al., 2012). It means that the chronological difference from top to bottom layers can be considered as about 40 ka. Such a difference is relatively short in geological time and all fossils from Layers 2–8 were considered as the members of the same fauna in the present work.

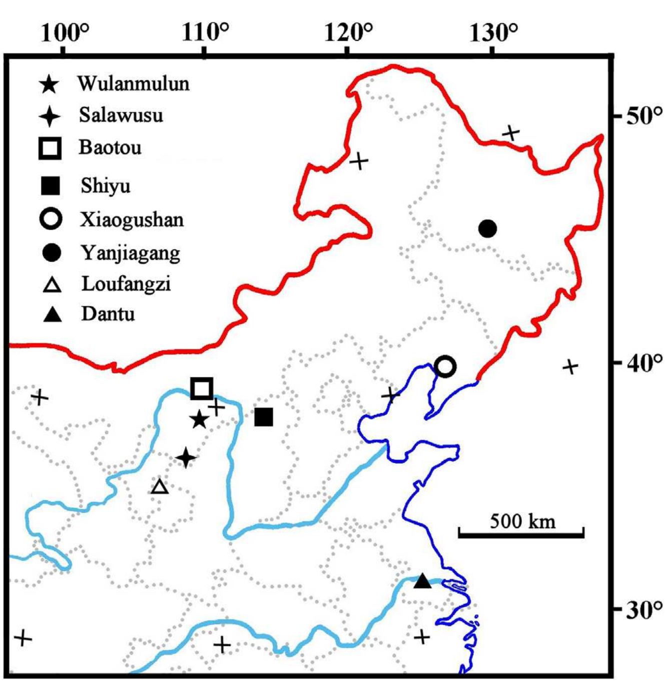

Fig. 1. Geographic locations of Wulanmulun Paleolithic Site and selected fauna sites.

3. Materials and methods

3.1. Materials

The present work dealt with mammal fossils collected in excavation campaigns at Wulanmulun Site from 2010 to 2012. Most of the specimens are very fragmental, chiefly due to human agency, and only hundreds of them are taxonomically identifiable. The latter form the main materials in the present systematic paleontology. All unearthed specimens are housed in the Ordos Museum.

Seven representative Late Pleistocene faunas (Fig. 1) were selected for fauna comparison. They are respectively from Salawusu (distance and heading from Wulanmulun on Google Earth: 235.12 km, 207.76°) in southern Ordos (Boule et al., 1928; Qi, 1975), Baotou (distance and heading from Wulanmulun on Google Earth: 116.27 km, 2.16°) in northern Ordos Plateau (Nie et al., 2008), Loufangzi (distance and heading from Wulanmulun on Google Earth: 420.42 km, 211.33°) in eastern Gansu Province and southmost Ordos (Huang, 1991), Shiyu (distance and heading from Wulanmulun on Google Earth: 222.53 km, 94.53°) in northern Shanxi of North China (Jia et al., 1972), Dantu (distance and heading from Wulanmulun on Google Earth: 1198.83 km, 130.55°) in Jiangsu Province of East China (Li et al., 1982), Xiaogushan (distance and heading from Wulanmulun on Google Earth: 1131.35 km, 80.15°) in Liaoning Province of northeastern China (Dong et al., 2010) and Yanjiagang (distance and heading from Wulanmulun on Google Earth: 1511.77 km, 58.19°) in Heilongjiang Province of northeastern China (Northeastern expedition team of Heilongjiang Managing Committee for Cultural Relics et al., 1987; Dong et al., 1999). The mammal fauna from the well-known Shuidonggou Site was not selected due to insufficiency of taxa. Faunas from Salawusu, Shiyu, Yanjiagang, and Dantu are associated with Late *Homo sapiens* (Wu et al., 1999); those from Salawusu, Loufangzi, Shiyu, Xiaogushan and Yanjiagang faunas are associated with Late Paleolithic artifacts (Dong et al., 2010; Hou et al., 2013); and that from Baotou is uniquely a fauna complex composed several fossil localities around Baotou City (Nie et al., 2008). The list of faunas from Wulanmulun and selected sites are in the online supplementary Table 1.

3.2. Methods

The mammalian fossils were firstly described using systematic paleontology. The fauna was then compared with selected representative Late Pleistocene faunas mentioned above. The fauna comparison methods followed that of Dong et al. (2010, 2013) according to Brainerd–Robinson's rule (Chen, 1983, 2005) and similarity coefficients. The fauna extinct rate is defined as the percentage of extinct taxa number divided by total taxa number of the fauna. The compared faunas are sorted in descending order according to the sequence by Brainerd–Robinson's rule, similarity coefficients to supposed archaic fauna, and extinct rates respectively. The sequences correspond to biochronological order from the oldest to the youngest. It is often the case that each fauna is sorted into a different position or sequence using the corresponding criterion. In order to get a comprehensive result, we defined a score for each fauna in each sequence as its sequence position number. We summed the three scores of a fauna in each sequence as its combined score, and sorted the faunas in descending order according to their combined scores.

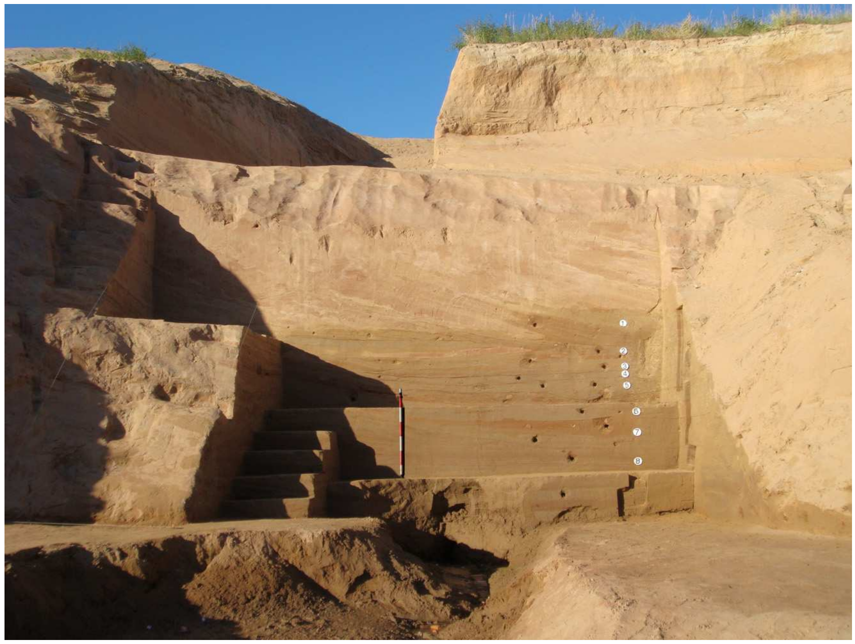

Fig. 2. Wulanmulun Site and exposed stratigraphic section.

The ecological composition of the faunas was based mainly on diet preferences of the fauna members. The diet and habitat preferences of taxa were based on the information from Nowak and Paradiso (1983) and Wang (2003). The ratios of different diet preferences were also compared in percentages.

4. Systematic paleontology

Mammalia Linnaeus, 1758
Perissodactyla Owen, 1848
Rhinocerotoidea Gill, 1872
Rhinocerotidae Owen, 1845
Dicerorhininae Simpson, 1945
***Coelodonta* Bronn, 1831**
***Coelodonta antiquitatis* (Bumenbach, 1807)**

4.1. Materials

A left mandibular fragment with p4-m3 (okw8G5-1); a left nearly complete mandible (okw10GC241) and partial *in situ* skeleton (Fig. 3). Several other fragmental jaws with broken teeth.

4.2. Description

The lower cheek teeth are relatively well preserved on mandibular fragment (okw8G5-1). They are typical of *C. antiquitatis* pattern, e.g. the lophids and buccal conids are less thick than those of *Stephanorhinus kirchbergensis*, the buccal enamel of buccal conids is undulated. The measurements of the cheek teeth and comparison with *C. antiquitatis* from other localities are listed in Table 1. The Wulanmulun teeth are nearly the same size as those from Xiaogushan (Dong et al., 2009), Yanjiagang (Northeastern expedition team of Heilongjiang Managing Committee for Cultural Relics et al., 1987) and Salawusu (Boule et al., 1928; Qiu et al., 2004). They also fall in the range of those from Europe and Siberia (Guérin, 1980). The thickness of the mandibular body (okw8G5-1) measures 58.9 mm at m2 and 58.1 mm at m3 (Fig. 3 A). The left mandible (okw10GC241) is massive and robust (Fig. 3 B). It retains nearly complete mandibular body and ramus. Its coronoid processus is set very low but its condyle processus very high. Its angular processus is nearly absent. The preserved post-cranial skeletons include cervical and thoracic vertebra, ribs, scapula, and limb bones (Fig. 3 C). Cement on the cheek teeth is observed on some fragmental jaws with broken teeth; the thickness of cement ranges from 0.8 to 2.7 mm.

Table 1
Measurements of the cheek teeth of *C. antiquitatis* from Wulanmulun and comparison with those from other localities (mm).

	okw8G5-1	Xiaogushan	Yanjiagang	Salawusu	Europe & Siberia
p4 L	40.4	42.3		38	35–48.5
p4 W	32.9	25.0		29	22–31.5
m1 L	36.3			45	38–56
m1 W	32.7			26	23–33
m2 L	50.9	50.7	50.7	52	42.5–58.5
m2 W	37.4	34.3	30.0	27	24–38.5
m3 L	56.4			56	47–62
m3 W	33.2				28–37
m1-3 L	140.8			147	123.5–181

Abbreviations: p. lower premolar; m. lower molar; L. length; W. width.
Data sources: Xiaogushan (Dong et al., 2009); Yanjiagang (Northeastern expedition team of Heilongjiang Managing Committee for Cultural Relics et al., 1987); Salawusu (Boule et al., 1928; Qiu et al., 2004); Europe and Siberia (Guérin, 1980).

Equidae Gray, 1821
***Equus* Linnaeus, 1758**
***Equus przewalskii* Poliakof, 1881**

4.3. Materials

An upper molar (okwGg80-1), M1 or M2; a right maxillary fragment with P2-4 (okw5G21-1); a right lower p2 (okw6G24-1); a right lower middle cheek tooth (okw6G24-2) and a left lower p2 (okw6G5-3) (Fig. 4).

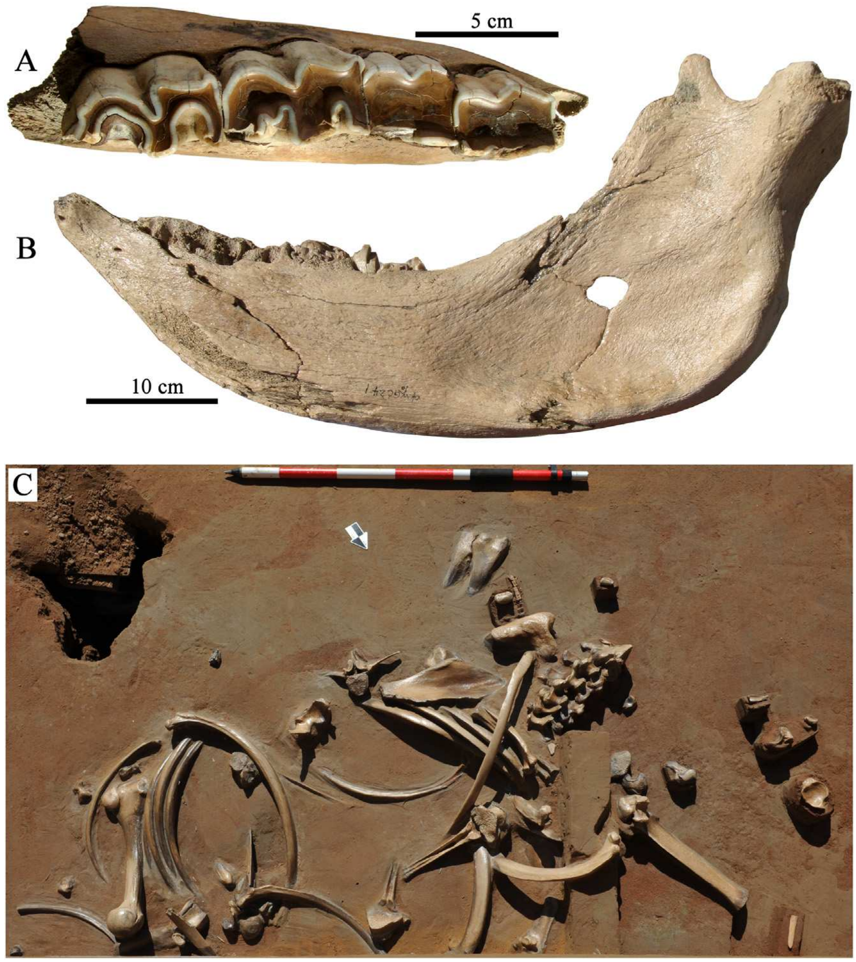

Fig. 3. Specimens of *Coelodonta antiquitatis*. A. Occlusal view of left mandibular fragment with p4-m3 (okw8G5-1); B. Buccal view of left nearly complete mandible (okw10GC241); C. partial skeleton *in situ*.

4.4. Description

The upper premolars are medium sized. The length of protocone increases from P2 to P4. Caballine, protoconule and hypostyle folds are developed in upper cheek teeth. Protoloph fold is developed in upper premolars but weak or absent in upper molars. The folds in mesial and distal fossettes are not numerous (Fig. 4 A, B). These characters are typical of *E. przewalskii* (Eisenmann, 1980; Deng and

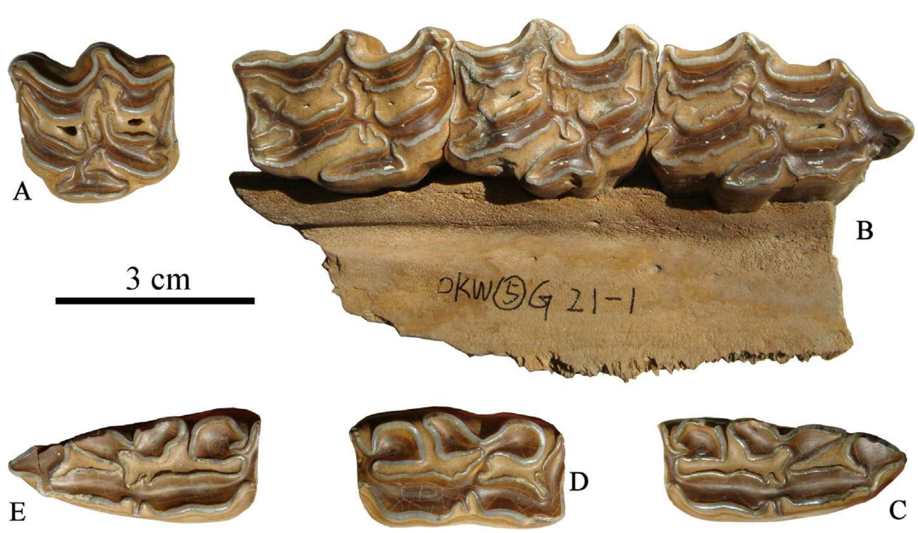

Fig. 4. Occlusal view of cheek teeth of *Equus przewalskii*. A. Middle upper cheek tooth (okwGg80-1); B. Right maxillary fragment with P2-4 (okw5G21-1); C. Right p2 (okw6G24-1); D. Right lower middle cheek tooth (okw6G24-2); E. Left p2 (okw6G5-3).

Xue, 1999). Table 2 shows that the dimensions of upper premolars from Wulanmulun are very close to those from Salawusu (Boule et al., 1928) and Loufangzi (Deng and Xue, 1999), as well as those of extant specimens (Zhou et al., 1985). The lower p2 is nearly triangular in occlusal view (Fig. 4 C, E). Its paraconid is developed and somewhat semi-circle in occlusal view. Its protoconid is relatively small with its buccal wall protruding slightly outward. Its hypoconid is relatively long and big with buccal wall slightly concave. Its cabaline fold is developed. Its metaconid and metastylid are nearly the same size and somewhat triangular in occlusal view. Table 2 shows that the dimensions of lower p2 from Wulanmulun are larger than those from Yanjiagang (Northeastern expedition team of Heilongjiang Managing Committee for Cultural Relics et al., 1987) and Loufangzi (Deng and Xue, 1999), as well as those of extant specimens (Zhou et al., 1985).

Table 2
Measurements of cheek teeth of *Equus przewalskii* from Wulanmulun and comparison with those from other localities (mm).

	Wulanmulun	Salawusu	Loufangzi	Extant
P2 L	40.5	37; 40	35.9	40–43
P2 W	21.8	25; 23	23.2	26.5–31.5
P2 PrL	10.1		7.7	
P3 L	30.0	29; 29	28.7	30–33
P3 W	24.6	29; 30	26.9	29.5–32.5
P3 PrL	11.0		12.5	
P4 L	32.8	27; 28	28.7	28.5–31
P4 W	24.6	29; 30	25.8	29.5–33
P4 PrL	14.0		12.8	
P2-4 L	102.6			100–107.5
		Yanjiagang		
p2 L	37.8; 38.2	30.8; 31.4	30.0–33.8	33.5–35
p2 W	18; 18.5	12.4; 12.1	13.1–15.4	16.5–19.5

Abbreviations: P. upper premolar; M. upper molar; p. lower premolar; L. length; W. width; Prl. length of protocone.
Data sources: Salawusu (Boule et al., 1928); Loufangzi (Deng and Xue, 1999); extant specimens (Zhou et al., 1985); Yanjiagang (Northeastern expedition team of Heilongjiang Managing Committee for Cultural Relics et al., 1987).

Artiodactyla Owen, 1848
Tylopoda Illiger, 1811
Camelidae Gray, 1821
Camelinae Gray, 1821
Camelini Gray, 1821
***Camelus* Linnaeus, 1758**
***Camelus* cf. *Camelus knoblochi* Nehring, 1901**

4.5. Materials

A right maxillary fragment with M2-3 (okw6G6-1).

4.6. Description

The upper molars are typical selenodont and mesohypsodont (Fig. 5 A). The upper M2 is broken, the lingual wall of its protocone is missing. Based on the preserved part of the tooth, the M2 is nearly the same as M3. The M3 is composed of four selenodont main cusps, the accessory elements such as cingula, neocrista, metaconule fold, metaconule spur, entostyle, etc. are all absent. The morphology of Wulanmulun specimen is very close to that described by Titov (2008). Table 3 shows that dimensions of Wulanmulun specimen are very close to those from Luchka, Razdorskaya and Sengiley in Russia (Titov, 2008). A left upper jaw fragment with canine, canine-like incisor and P2, and some postcranial bones of *C. knoblochi* were reported from Salawusu (Boule et al., 1928; Qi, 1975), but a counterpart of the Wulanmulun specimen is absent from Salawusu materials. Because the teeth size criterion is not very dependable for late camels and the Late Pleistocene is the period of the appearance of *Camelus bactrianus* in Asia, the inclusion of the present materials into *C. knoblochi* still needs the finding of more informative material such as skulls or metapodiums.

Table 3
Measurements of *Camelus knoblochi* from Wulanmulun Site and comparison with that from Russia (mm).

Locality	Wulanmulun	Luchka	Razdorskaya	Sengiley
Specimen	okw6G6-1	8678 type*	ROMK*	7/2932*
M2 L	55.4	51.0	42.0; 41.6	54.3; 53.0
M2 W	34.4	38.0	36.6; 37.9	37.3; 35.3
M3 L	57	59.0	52.0; 52.7	61.4; 61.3
M3 W	35.1	35.0	36.1; 36.8	35.0; 25.0

Abbreviations: M. upper molar; L. length; W. width.
*Data sources: Luchka, Razdorskaya and Sengiley (Titov, 2008).

Ruminantia Scopoli, 1777
Cervidae Gray, 1821
Cervinae Baird, 1857
***Megaloceros* Brookes, 1828**
***Sinomegaceros* Dietrich, 1933**
***Megaloceros (S.) ordosianus* (Young), 1932**

4.7. Materials

Two antler bases (11kw6a547, okw10GC128) (Fig. 5 B–C).

4.8. Description

Both antlers are shed ones. The brow tine is set very low and very close to the burr. The brow tine is palmate from the tine base that distinguishes it from *M. (S.) yabei*. The angle between the brow tine and main beam is very large. The ornament of the antler is composed of longitudinal furrows and ridges. The brow tine and main beam of the specimens are broken, but the original brow tine and main beam are flattened or distally palmate (Huang et al., 1989). Measurements for okw10GC128 (Fig. 5 C): maximum diameter of the pedicle scar 45.6 mm; minimum and maximum diameters of burr, 52.6 mm and 53.8 mm; minimum and maximum diameters of main beam base, 27.4 mm and 37 mm. Although *Megaloceros* was recognized as the valid generic name for giant deer by the International Commission for Zoological Nomenclature (Lister, 1987), a frequent synonym of *Megaloceros* in some publications is *Megaceros* (e.g. Chow and Wang, 1988; Huang et al., 1989). However, *Megaloceros* is the valid name (Dong and Jiang, 1993).

Bovidae Gray, 1821
Antilopinae Baird, 1857
***Gazella* Blainville, 1816**
***Gazella* sp.**

4.9. Materials

A right astragal, or talus (12kwI6B13:215, Fig. 5 D) and an intermediate phalange (11kw7c704, Fig. 5 E).

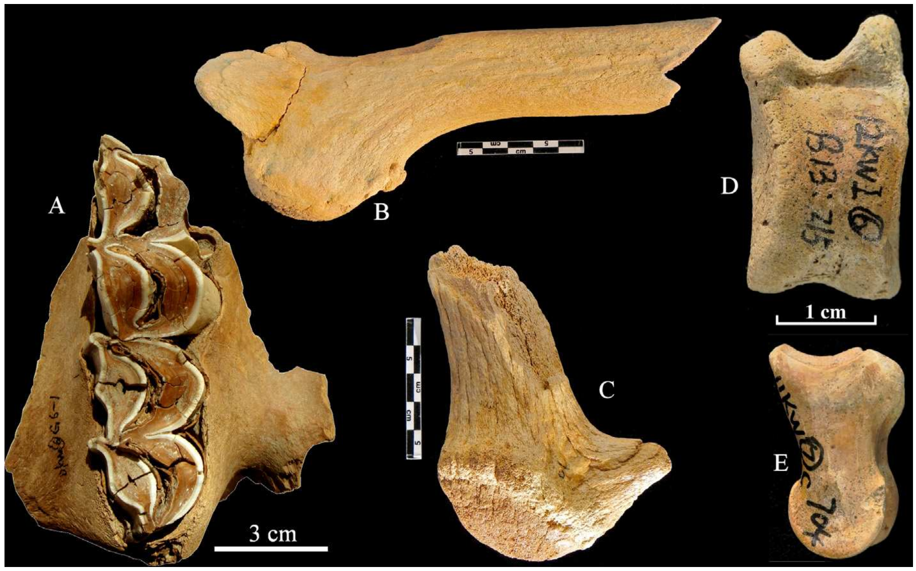

Fig. 5. Specimens of Artiodactyla. A. Occlusal view of right maxillary fragment with M2-3 (okw6G6-1) of *Camelus knoblochi*; B. Proximal fragment of a shed antler of *Megaloceros ordosianus* (11kw6a547); C. Antler base of *Megaloceros ordosianus* (okw10GC128); D. Posterior view of right talus (12kwI6B13:215) of *Gazella* sp.; E. Middle second phalange (11kw7c704) of *Gazella* sp.

4.10. Description

Two trochleae are present on the talus (12kwI6B13:215, Fig. 5 D), a tibial or proximal one and a cubonavicular or distal one. The groove on the tibial trochlea is deeper than that on the cubonavicular one. This groove separates the two lips of the trochlea. The lateral trochlear lip is more developed than the medial one, forming a lateral beak and an asymmetrical tibial groove. The cubonavicular groove and lips are less developed and nearly symmetrical. The maximal transversal diameter of the talus measures 16.88 mm, the lateral (maximal) height of the talus measures 28.46 mm.

The proximal surface of the phalange (11kw7c704, Fig. 5 E) is well developed and is composed of a medial and a lateral glenoid cavities and an intermediate groove. Both cavities are nearly equally developed. The distal end of the phalange is also well developed and is composed of medial and lateral condyles. The body of the phalange is relatively less developed. The maximal transversal diameter of the phalange measures 13.02 mm, the anterior (dorsal) height of the phalange measures 20.04 mm and the maximal transversal diameter of the phalange measures 8.08 mm. The described astragal and phalange are temporarily included into *Gazella*, but alternatively they might be related to *Procapra przewalskii*.

Besides the above described 5 hoofed mammal taxa, 6 rodents, a largomorpha, and a carnivore were identified at generic or familial level: *Myospalax* sp., *Cricetulus* sp., *Microtus* sp., *Apodemus* sp.,

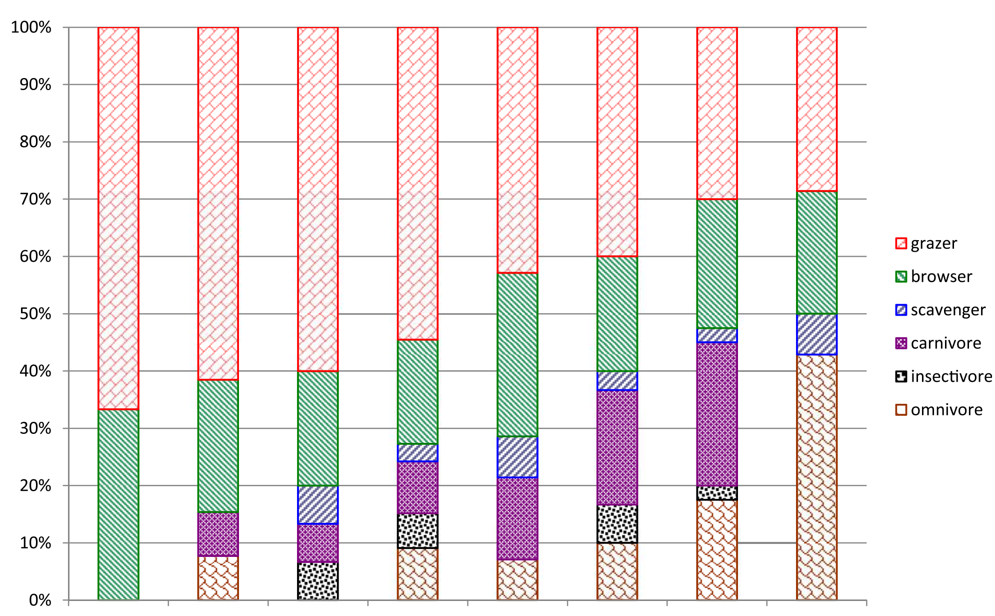

Fig. 6. Comparison of ecological composition between Wulanmulun fauna and selected Late Pleistocene faunas.

Arvicola sp.?, Dipodidae gen. et sp. indet., *Lepus* sp., Mustelidae gen. et sp. indet. They are present in the Wulanmulun fauna and they are regarded as a paleontological fauna in the present work.

5. Results of fauna analyses and discussion

The sequenced faunas from Wulanmulun and selected representative Late Pleistocene localities according to Brainerd–Robinson's rule and similarity coefficients are shown in Table 4. Table 5 lists the chronologically sequenced faunas according to three different criteria such as Brainerd–Robinson's rule, similarity coefficients with supposed archaic fauna, and extinction rates. The ecological compositions according to diet preferences of Wulanmulun and compared faunas are illustrated in Fig. 6.

Table 4
Sequenced faunas according to Brainerd–Robinson's rule and similarity coefficients with supposed archaic and extant faunas.

Sequenced	Archaic	Baotou	Wulanmulun	Shiyu	Loufangzi	Salawusu	Dantu	Yanjiagang	Xiaogushan	Extant
Archaic	156									
Baotou	111	156								
Wulanmulun	103	136	156							
Shiyu	98	101	127	156						
Loufangzi	101	130	124	137	156					
Salawusu	84	105	103	114	119	156				
Dantu	105	124	56	117	118	89	156			
Yanjiagang	79	105	99	110	105	88	101	156		
Xiaogushan	100	87	83	101	97	80	85	101	156	
Extant	6	47	55	60	57	83	101	76	54	156

Table 5
Biochronologically sequenced faunas based on three different criteria and combined scores.

Fauna sequence	B-R antiquity	Fauna sequence	Archaic coefficient	Fauna sequence	Extinct rate%	Fauna sequence	Combined scores
Baotou	(8)	Baotou	111 (8)	Baotou	55.56 (8)	Baotou	24
Wulanmulun	(7)	Dantu	105 (7)	Xiaogushan	37.50 (7)	Dantu	16
Shiyu	(6)	Wulanmulun	103 (6)	Dantu	35.71 (6)	Loufangzi	15
Loufangzi	(5)	Loufangzi	101 (5)	Loufangzi	28.57 (5)	Wulanmulun	14
Salawusu	(4)	Xiaogushan	100 (4)	Salawusu	28.13 (4)	Xiaogushan	12
Dantu	(3)	Shiyu	98 (3)	Shiyu	26.67 (2.5)	Shiyu	11.5
Yanjiagang	(2)	Salawusu	84 (2)	Yanjiagang	26.67 (2.5)	Salawusu	10
Xiaogushan	(1)	Yanjiagang	79 (1)	Wulanmulun	23.08 (1)	Yanjiagang	5.5

N.B. Figure in brackets is sequence score.

5.1. Fauna similarity sequences

Table 4 shows that the faunas adjacent to the Wulanmulun fauna are the Baotou and Shiyu. The Baotou and Shiyu faunas are closest to the Wulanmulun fauna according to Brainerd–Robinson's rule and similarity coefficients, followed by the Loufangzi, Salawusu, Dantu, Yanjiagang and Xiaogushan faunas. If we consider the similarity coefficients alone, the Wulanmulun fauna is the most similar to that of Baotou (136), followed by Shiyu (127), Loufangzi (124), Salawusu (103), Yanjiagang (99), Xiaogushan (83), and Dantu (56). Both results show that the Wulanmulun fauna is closer to the faunas from Ordos Plateau (Baotou, Loufangzi and Salawusu) or near Ordos Plateau (Shiyu), and it is less close to the faunas from Northeast China (Xiaogushan and Yanjiagang) and East China (Dantu).

In ecological composition, the Wulanmulun fauna is closest to Shiyu, Baotou, and Salawusu faunas. They are characterized by large proportions of grazer taxa. The following closer faunas are Loufangzi, Yanjiagang, Xiaogushan, and Dantu in descending order (Fig. 6). The Wulanmulun fauna is ecologically incomplete due to the absence of insectivores and scavengers. This does not indicate their absolute absence from the Wulanmulun area, because the mammalian remains in the site were likely selected from available taxa of that time by prehistoric human inhabitants.

5.2. Biochronological sequences

From Table 4, the Baotou fauna is the closest to supposed archaic fauna, followed consecutively by the Wulanmulun, Shiyu, Loufangzi, Salawusu, Dantu, Yanjiagang and Xiaogushan faunas. Sorting the faunas according to the similarity coefficients between supposed archaic fauna and concerned faunas, the Baotou fauna is the closest one to supposed archaic fauna (111), followed successively by Dantu (105), Wulanmulun (103), Loufangzi (101), Xiaogushan (100), Shiyu (98), Salawusu (84), and Yanjiagang (79). Comparing the extinction rate of the faunas, the sequence becomes Baotou (55.56%), Xiaogushan (37.50%), Dantu (35.71%), Loufangzi (28.57%), Salawusu (28.13%), Shiyu (26.67%), Yanjiagang (26.67%), and Wulanmulun (23.08%). Table 5 lists the chronologically sequenced faunas according to three different criteria such as Brainerd–Robinson's rule, similarity coefficients with supposed archaic fauna and extinction rates. The Baotou fauna is always the oldest one and Loufangzi the fourth oldest one according to all three criteria. Yanjiagang fauna is the youngest one according to archaic coefficient or the second youngest one according to both B-R's Rule antiquity and extinction rate. The other faunas are much less consistent. The fauna sequence sorted by combined scores is listed in the right columns of Table 5, and it is the proposed biochronological sequence of the faunas concerned. The Wulanmulun fauna (combined score = 14) is slightly younger than Loufangzi fauna (15) and Dantu fauna (16), evidently younger than Baotou fauna (24), slightly older than Xiaogushan fauna (13) and Shiyu fauna (11.5), older than Salawusu fauna (10), and much older than Yanjiagang fauna (5.5).

5.3. Paleoecological composition and paleoenvironment

For ecological composition (Fig. 6), the Wulanmulun fauna is dominated by grazer taxa such as *Myospalax* sp., *Apodemus* sp., *Arvicola* sp.?, Dipodidae gen. et sp. indet., *Lepus* sp., *E. przewalskii*, *Camelus* cf. *C. knoblochi*, *Gazella* sp. They represent more than 60% of total taxa. If partially grazer taxa such as *Microtus* sp., *Cricetulus* sp. are included, the grazer taxa of the Wulanmulun fauna represent nearly 80% of total taxa. Browser taxa such as *C. antiquitatis* and *M. ordosianus* represent a little less than 20% of total taxa. Both carnivore and omnivore taxa comprise less than 10% of total taxa respectively. Most taxa are temperate habitat dwellers, and only *C. antiquitatis* is mostly a cold habitat dweller and *C. knoblochi* is partially a cold habitat dweller. Many taxa such as *Cricetulus* sp., Dipodidae gen. et sp. indet., *E. przewalskii* and *Gazella* sp. prefer dry habitats, *Apodemus* sp., *Myospalax*, *Microtus*, *Lepus* sp., Mustelidae gen. et sp. indet. and *Camelus* cf. *C. knoblochi* appear usually in both dry and humid habitats, while *M. ordosianus* and *C. antiquitatis* prefer partially humid habitats and only *Arvicola* prefers humid habitat. As the fossil specimens are dominated by *C. antiquitatis*, the comprehensive indication of vegetation and habitats in Wulanmulun Site area might have been a mixture or mosaic of grassland and forest with partially humid and temperate climate. The fluctuation of annual temperature might have been high with the winter very cold and the summer relatively warm.

5.4. Paleozoogeographical consideration

The most common taxa in compared faunas are *C. antiquitatis*, *E. przewalskii*, and *M. ordosianus*. They are present in all compared faunas except the Dantu fauna from East China. They are typical Late Pleistocene herbivores of the Palearctic Province distributed in Northwest, North and Northeast China. *C. antiquitatis* was considered to be derived from *Coelodonta nihowanensis* in the early Pleistocene (Deng et al., 2011) and reached its maximum distribution all over northern Eurasia in the Late Pleistocene (Kahlke and Lacombat, 2008). More than 50 fossil localities in China are mostly distributed in northern China (Chow, 1978; Tong and Moigne, 2000). *E. przewalskii* is an endemic species of northern China and Mongolia. Its fossil remains are very rich at Shiyu Paleolithic site of Shanxi Province in North China (Jia et al., 1972) and its Late Pleistocene distribution mostly ranges from Northwest and North to Northeast China. Its southernmost locality was found on the sea bottom of the Penghu archipelago near the Tropic of Cancer, and it was considered to have migrated there during the last glacial period when the cold areas expanded southward, the sea level dropped, and the archipelago was connected to the mainland (Gao, 1982). *M. ordosianus* is an endemic species of northern China. It has been found only in northern China. The presence of these three taxa in the mentioned faunas is therefore reasonable.

The second common taxa in the compared faunas are *Crocuta ultima*, *Cervus elaphus* and *Bubalus wansjocki*. *C. ultima* is absent only from the Wulanmulun and Baotou faunas. It is a widely ranged fossil taxon of both Palearctic and Oriental Provinces as well as the transitional zone, recovered from all parts of China. *C. elaphus* is absent only from Wulanmulun and Dantu faunas. It is a Late Pleistocene and Holocene browser and opportunistic grazer of the Palearctic Province. Its absence from the Dantu fauna is reasonable, but the absence from the Wulanmulun fauna is probably due to the fragmental state of the most fossil specimens. *B. wansjocki* is absent from the Wulanmulun and Loufangzi faunas. It is a Late Pleistocene water buffalo of the Palearctic Province and Transitional Zone. It might be present in both Wulanmulun and Loufangzi faunas.

The third common taxa in compared faunas are *Sus scrofa* and *P. przewalskii*. *S. scrofa* is a typical Late Pleistocene and Holocene omnivore and is widespread throughout Eurasia. It has wide adaptability and is only absent from very arid and cold areas of Eurasia. It will not be a surprise if it is recovered one day from all localities of compared faunas. *P. przewalskii* is rather a typical Late Pleistocene and Holocene grazer limited to the Nei Mongol Plateau and surrounding areas. Its presence in the Wulanmulun fauna is possible, and the astragal and phalange of *Gazella* sp. in Fig. 5 might be alternatively related to *P. przewalskii*.

Panthera tigris and *Equus hemionus* are the fourth common taxa in the compared faunas. *P. tigris* is a typical carnivore and forest dweller of the Late Pleistocene and Holocene. It is absent from the Wulanmulun, Baotou, Yanjiagang, and Dantu faunas but is present in the Xiaogushan, Shiyu, Salawusu, and Loufangzi faunas. *E. hemionus* is a typical Late Pleistocene and Holocene grazer of Nei Mongol Plateau and surrounding areas. It is absent from the Wulanmulun, Baotou, Xiaogushan and Dantu faunas but present in the Salawusu, Loufangzi, Shiyu, and Yanjiagang faunas. Its absence from the Dantu fauna is reasonable, but it might be present in the Wulanmulun, Baotou, and Xiaogushan faunas.

The other taxa in compared faunas are sporadically present and their appearances are not frequent. *Mammuthus* is present only in the Yanjiagang and Xiaogushan faunas in Northeast China and is absent from the other compared faunas in Northwest, North, and East China. This indicates that Northeast China is colder than North and Northwest China in the Late Pleistocene. Northeast China is a zoogeographically different sub-province from North and Northwest China.

5.5. Conclusions

The Wulanmulun fauna is composed mainly of large hoofed mammals. Based on the fauna composition, vegetation and habitats in the Wulanmulun Site area might have been a mixture or mosaic of grassland and forest with some small streams and swamps. The fluctuation of annual temperature might have been high with the winter very cold and the summer relatively warm.

According to Brainerd–Robinson's rule, similarity coefficients, and ecological composition, the Wulanmulun fauna is the closest to Baotou and Shiyu faunas. It is close to the Loufangzi and Salawusu faunas, but less close to the Xiaogushan, Yanjiagang, and Dantu faunas.

With comprehensive consideration of Brainerd–Robinson's rule and similarity coefficients with supposed archaic and extant faunas, as well as extinction rates of the faunas, the Wulanmulun fauna is slightly younger than the Loufangzi fauna and Dantu fauna, evidently younger than the Baotou fauna, slightly older than the Xiaogushan and Shiyu fauna, older than the Salawusu fauna, and much older than the Yanjiagang fauna.

The Wulanmulun fauna lies in the same paleozoogeographic sub-province as the Baotou, Shiyu, Salawusu and Loufangzi faunas, different from that of the Xiaogushan and Yanjiagang faunas of Northeast China, and more different from the Dantu fauna of East China. The Wulanmulun area was suitable for the habitation of the late Paleolithic humans, and the Wulanmulun fauna were their main hunting prey.

Acknowledgements

The authors would like to acknowledge Profs. W.-w. Huang, B.-y. Yuan, B.-s. Li, J.-f. Zhang and excavation team of Wulanmulun Site for joint field work. They would also like to thank Prof. C.-z. Jin and Dr. Y. Wang for identifying rodent specimens. They are grateful to Dr. C. Griggo for identifying some uncertain specimens and to two reviewers for suggestions to improve the manuscript. The present work was supported by the CAS Strategic Priority Research Program Grant (No. XDA05130302), National Natural Science Foundation of China (No. 41272033, 41372027).

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quaint.2014.05.051.

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