



# The large mammals from Tuozidong (eastern China) and the Early Pleistocene environmental availability for early human settlements

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## ABSTRACT

To test the possibility if the earliest human settlements in Eurasia could be earlier than commonly accepted 1.7 Ma, large mammals from the Tuozidong cave deposits from eastern China were analyzed. Tuozidong deposits were discovered in 2000 and excavated again in 2007. Compared with other Eurasian Early Pleistocene faunas, the Tuozidong fauna is similar to Yuanmou and Gongwangling faunas associated with *Homo erectus*, indicating that the environments of Tuozidong fauna were suitable for habitation of early humans. It is similar to the Longgupo and Renzidong faunas associated with putative Paleolithic industry around 2 Ma in China. It is also similar in some degree to the Saint Vallier and Chilhac faunas in France, which indicates the existence of faunal exchanges between East Asia and West Europe, and the environment barriers between Eurasian continents were not unconquerable in the early Pleistocene for mammal migrations. Based on the capability of good mammal migrators, the earliest tool-makers of 2.6 Ma in East Africa should have been able to expand or migrate to Eurasia within 600 ky. The putative Paleolithic industries from Longgupo and Renzidong in East Asia and those from Riwat in South Asia might be the witness of earliest human settlements in Eurasia around 1.9–2 Ma.

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## 1. Introduction

The Nanjing Man (*Homo erectus*) Site at Huludong (Calabash Cave) was found in 1992 in Nanjing Municipality, Jiangsu Province of eastern China (Mu et al., 1993). Some follow-up investigations for searching new evidence of human evolution at and around Huludong were carried out in the following years (Hua, 1996; Zhou and Liu, 2002). A new mammalian fauna was discovered consequently in 2000 from Tuozidong (Humpback Cave) cave deposits in the same area. The site was excavated in 2000, large quantities of mammal fossils were collected, and the fauna was dated as the Early Pleistocene (Fang et al., 2007) contemporary to that associated with the Early Paleolithic industry of Longgupo (Huang et al., 1991; Boëda and Hou, 2011) and Renzidong (Jin and Liu, 2009) with an age around 2 Ma, a sensitive age for acceptance of early human settlements in Eurasia by most archaeologists and paleo-anthropologists (Breuil, 1935; Teilhard de Chardin, 1941; Delson, 1989; Huang et al., 1995, 1996; Wood and Turner, 1995; Raynal

et al., 1996; Schwartz and Tattersall, 1996; Wang, 1996; Raynal and Magoga, 2000; Wu, 2000; Dennell, 2003; Etler, 2004; Dong, 2006; Ciochon, 2009; Boëda and Hou, 2011). In an attempt to find early human traces, Tuozidong was excavated again in 2007. In addition to large mammals, many small mammals were screened (Dong and Fang, 2008). Although no convincing early human traces were found at the site, the excavation provided enriched fossil materials for discussion of environmental availability for early human settlements.

## 2. Regional setting

Tuozidong (GPS: 32°03'17.1"N, 119°01'57.6"E, 114 m) is located on Tuozijian (Humpback Hill) in Jiangning District of Nanjing Municipality, about 872 m west (244°36'N) of Huludong of Nanjing Man Site (Fig. 1) and 26 km east of Nanjing City. It is about 141 km northeast of Renzidong (Tent-shaped Cave) Site in East China and about 900 km east of Longgupo (Dragon-bone Slope) Site in Central China (Fig. 1). Tuozidong was a karst cave, developed probably during the Neogene in a joint of Honghuayuan (Safflower Garden) Formation of Ordovician limestone. The cave deposits were formed in the Early Pleistocene. The cave entrance was completely covered by deposits, likely in early stage of the Middle Pleistocene. It was

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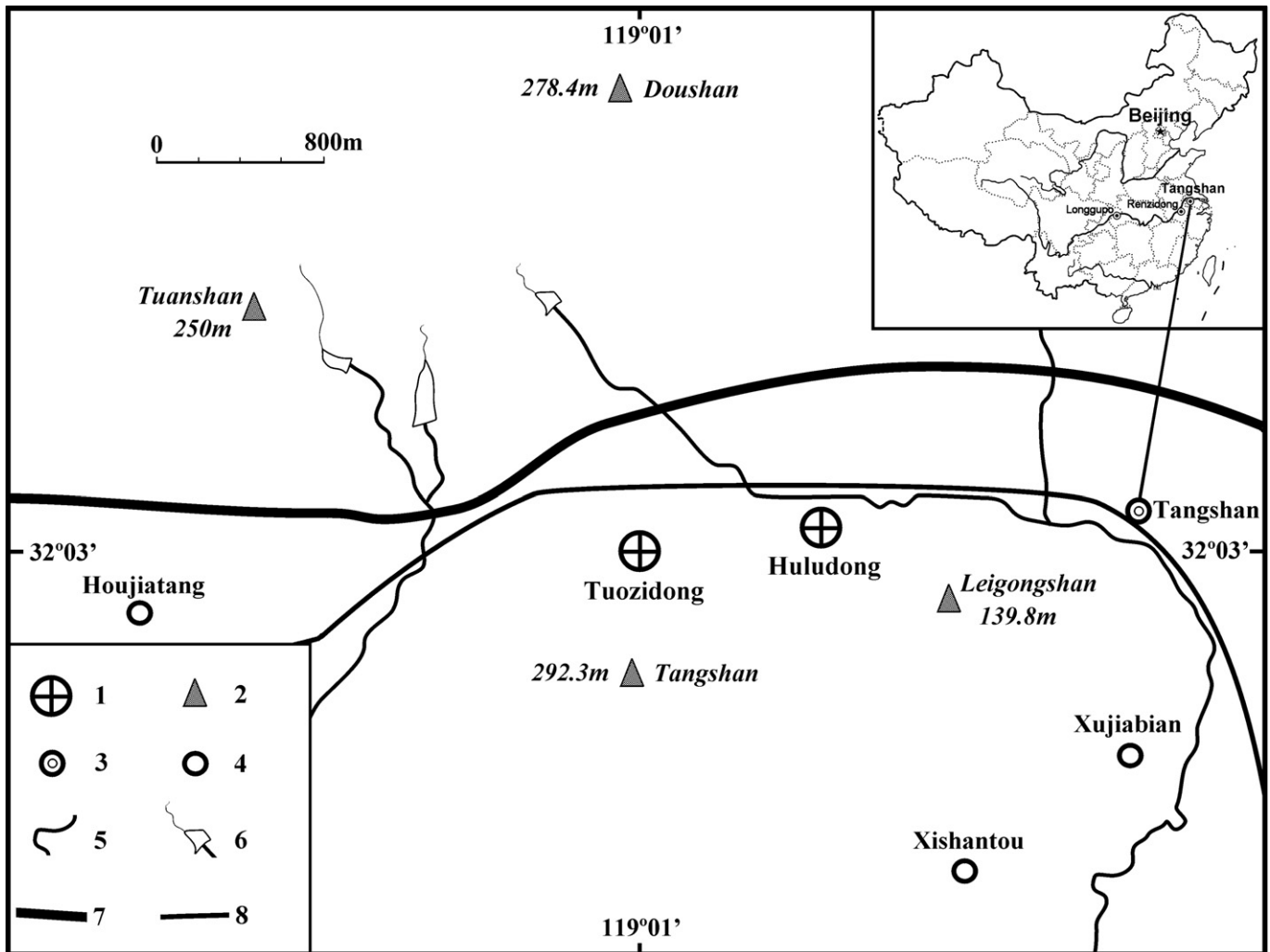


Fig. 1. Location map of Tuozidong: 1. fossil locality; 2. peak; 3. commune; 4. village; 5. stream; 6. reservoir; 7. national road; 8. provincial road.

uncovered during limestone mining in the 1990s by local miners and the roof of the cave was found to have collapsed.

The *in situ* investigation shows that the original cave was developed roughly north–south. Its entrance opened northwards and turned a little eastwards and the cave terminated southward with a total length of about 20 m. The largest part of the cave is located in the north with a width at least 8 m and a height at least 5 m.

The cave deposits can be divided into three parts. The upper part is composed mainly of red clay, with scattered fossil fragments and limestone gravels. Its thickness varies from 20 cm to 30 cm and with a maximum of 130 cm in some limited areas. This part was formed probably after the closure of the cave entrance. The sediments were washed into the cave along some fissures and covered on the middle part of the deposits. The middle part is composed mainly of reddish yellow sandy clay with rich fossils and some limestone gravels. Its maximum thickness measures 2 m. Some parts of the deposits were strongly cemented by calcareous underground water and conglomerated. A piece of small quartz sandstone gravel with a length of 83 mm, a width of 72 mm and a thickness of 43 mm, and a silex flake with a length of 30 mm and sharp edges were found in the middle part. Although these two unworn specimens are not from the karst cave or vicinity, no convincing human modifications were observed. Their presence in

the deposits is difficult to interpret. The lower part is composed of yellow sandy clay with clear horizontal stratification and some limited limestone breccias. The calcareous cementation is evidently reduced in this part. The fossil materials decrease in this part, and often are too fragmented to be identifiable. The thickness of this part is greater than 2 m.

The statistics of the wearing status of fossil specimens from Tuozidong deposits based on 3820 randomly selected specimens show that 95.4% of specimens are not worn, 3.6% slightly worn, and only 0.9% medially worn and 0.1% heavily worn. The orientations of long bones are irregular. This indicates that the most specimens were buried with little transportation and the bone sources were in the cave or not far away from the cave. The cave most likely functioned as a natural trap of large mammals during the accumulation of the middle and upper parts of the deposits. The animals might fall into the cave from some vertical fissures above the cave, were killed or severely wounded and finally died in the cave. The shape of the cave and the orientation of cave entrance also allowed it to serve as a carnivore den during the deposition period of the middle part of the sediments. The cave might be a good place for carnivores to store and enjoy their prey, and killed or wounded large mammals that fell into the cave from the fissures might also be a good meat source for them. The sandy clay deposits are aqueous, washed into the cave during rainy seasons. The sandy clay was washed through

the cave seasonally and deposited in the cave with the accumulation of the animal bones and with the limestone gravel fallen from the cave and fissure walls.

### 3. Material and methods

#### 3.1. Material

The fossils uncovered in the field excavation in 2000 have been described, and the identified taxa are as follows: *Sinocastor* sp., *Macaca peii*, *Nyctereutes sinensis*, *Martes* sp., *Eirictis* sp., *Meles* sp., *Ursus* sp., *Megaviverra pleistocaenica*, *Pachycrocuta perrieri*, *Lynx shansius*, *Felis* (?*Puma*) sp., *Acinonyx arvernensis*, *Felis* sp., *Stegodon* cf. *preorientalis*, *Stephanorhinus kirchbergensis*, *Hipparion* (*Probosciparion*) *sinense*, *Equus huanghoensis*, *Sus lydekkeri*, *Metacervulus* cf. *capreolinus*, *Cervavitus ultimus*, *Axis shansius jiangningensis*, *Cervus* (*Sika*) cf. *grayi*, *Cervus* (*Sika*) cf. *magnus*, *Megalovis guangxiensis*, *Gazella sinensis*, *Leptobos* (*Smertiobos*) cf. *crassus* (Fang et al., 2007). The large mammals uncovered in field work in 2007 are taxonomically similar to the previously excavated ones, but some of them include complementary parts. For example, *M. peii* was found as lower jaws in 2000, but as a right maxillary fragment in 2007. The small mammals are still under study. The present work dealt with large mammals collected in two excavation campaigns.

Early Pleistocene faunas from different areas of China such as Renzidong (distance and heading from Tuozidong on Google Earth: 141.26 km, 219.03°) in eastern China (Jin and Liu, 2009; Jin et al., 2009b), Longgupo (899.69 km, 263.98°) (Huang et al., 1991) and Longgudong (865.62 km, 262.05°) (Zheng, 2004) in central China, Juyuangong (1277.02 km, 231.10°) (Han, 1987; Pei, 1987), Dadong (1572.54 km, 229.13°) (Jin et al., 2009a), Mohui (1510.50 km, 234.42°) (Wang et al., 2007) and Yuanmou Man Site (1810.88 km, 251.28°) (Lin et al., 1978) in southern China, Xiaochangliang (986.96 km, 337.89°) (Tang et al., 1995) and Danangou of Yuxian (972.13 km, 337.81°) (Tang et al., 2000) in northern China, Gongwangling (920.75 km, 287.50°) (Hu and Qi, 1978) and Longdan (1488.76 km, 289.29°) (Qiu et al., 2004) in northwestern China, and that from the crossroads of Western Asia and Eastern Europe such as Dmanisi (6548.47 km, 302.11°) of Georgia (Gabunia et al., 2000), and those from West Europe such as Saint Vallier (9187.04 km, 319.57°) (Guérin et al., 2004) and Chilhac (9273.37 km, 320.17°) (Boeuf, 1985, 1995) of France, were selected for comparison. Those from Yuanmou, Gongwangling and Dmanisi are associated with *Homo*, and those from Renzidong, Longgupo, Longgudong, Xiaochangliang, Yuxian, Saint Vallier and Chilhac are associated with either accepted or controversial Paleolithic industries.

Every selected fauna for comparison is from fossiliferous deposits of a site. Some deposits have been subdivided according to stratigraphic characteristics. For example, Renzidong, Longgupo, Longgudong and Saint Vallier sites have more than two subdivided fossiliferous levels, and there are some differences between different levels. However, the time interval between the top and bottom levels of these sites is not large, especially compared with their ages. Fauna dispersal and exchange need a considerable period to accomplish. To illustrate the results of faunal dispersal and exchange results, the taxa from all subdivided fossiliferous levels are considered as one fauna in the present study.

#### 3.2. Methods

The Tuozidong fauna was compared with the selected representative Early Pleistocene using the following method: firstly, all extinct or archaic taxa from Tuozidong fauna and selected other faunas were listed as a supposed archaic fauna; the remaining extant taxa were regarded as a supposed extant fauna. Secondly,

the Tuozidong fauna, selected faunas and supposed archaic and extant faunas were compared in pairs to determine the Brainerd-Robinson's similarity coefficients. Thirdly, all compared faunas were sequenced in Table 1 according to Brainerd-Robinson's rule and similarity coefficients (Chen, 1983, 2005). The method was originally tried by Chen to find the chronological sequence of different prehistoric faunas but limited to faunas in the same zoogeographic province (Chen, 1983). Although the method is not very effective with faunas in different zoogeographic provinces, it was tested as helpful to find the similarity of the faunas from different provinces (Dong et al., 2010). The faunas that are closely related will appear side by side in the ranked table.

The chronological sequence of the compared faunas was estimated by sorting the Brainerd-Robinson's similarity coefficients between the supposed archaic fauna and the faunas from Tuozidong and the selected localities. The coefficients are referred here as antiquity coefficients in Table 2. In addition, the extinction rate (percentage of extinct taxa over total taxa of the fauna) of the faunas was calculated. The two methods result in different outcomes, and their synthesis was regarded as the recommended conclusion based on large mammal materials.

The ecological composition of the faunas was based mainly on diet preferences of the fauna components. The diet and habitat preferences of the extant taxa were based on the information from Nowak and Paradiso (1983) and Wang (2003). For extinct taxa, those of the closest extant relatives of extinct taxa were taken as equivalents. The ratios of different diet preferences were also compared in percentage. They were helpful indications for paleo-environmental reconstruction.

### 4. Results

The ranked faunas according to Brainerd-Robinson's rule and similarity coefficients are listed in Table 1. As far as the similarity coefficients are concerned, i.e. without considering the similarity to supposed archaic and extant faunas, the Tuozidong fauna is most similar to that of Xiaochangliang, with a coefficient of 316, and then descendingly to that of Yuxian (314), Chilhac (300), Yuanmou (298), Mohui (294), Dmanisi (290), Gongwangling (288), Dadong (286), Renzidong (282), Longgupo and Longdan (both 280), Saint Vallier and Juyuangong (both 266), and lastly Longgudong (264). Taking both the similarity coefficients between Tuozidong fauna and the selected faunas and those between all compared faunas and supposed archaic and extant faunas into account, the Yuxian and Yuanmou faunas, next to the Tuozidong fauna in Table 1, are most similar.

Considering the similarity coefficients with supposed archaic fauna (Tables 1 and 2), Tuozidong fauna (100) is next to that of Longgudong (102) and Renzidong (96). For extinction rates (Table 2), Tuozidong fauna (76%) is close to that of Longgudong (76.2%) and Renzidong (69.7%). Biochronologically sequenced faunas based on large mammals are synthesized in Table 2.

For ecological composition, the Tuozidong fauna is very similar to Gongwangling and Dmanisi faunas which were associated with early humans. The Tuozidong fauna is also similar to Longgudong and Chilhac faunas, and similar in some degree to Saint Vallier, Juyuangong and Renzidong faunas (Fig. 2). The Chilhac and Dmanisi faunas have the same ecological compositions.

Compared with habitat preferences of their extant or closest extant forms (Nowak and Paradiso, 1983; Wang, 2003), forest and woodland prone taxa in the Tuozidong fauna are *Sinocastor* sp., *M. peii*, *N. sinensis*, *Ursus* sp., *Me. pleistocaenica*, *L. shansius*, *Felis* (?*Puma*) sp., *Felis* sp., *St. cf. preorientalis* and *S. kirchbergensis*, *Su. lydekkeri*, *Met. cf. capreolinus*, *C. ultimus*, *Ax. shansius jiangningensis*, *Ce. (Sika)* cf. *grayi*, and *Ce. (Sika)* cf. *magnus*. They indicate a considerable range

**Table 1**  
Similarity sequence according to Brainerd-Robinson's rule and similarity coefficients.

	Archaic	St Vallier	Chilhac	Dmanisi	Xiaochangliang	Yuxian	Tuozidong	Yuanmou	Mohui	Dadong	Juyuandong	Longgupo	Longgudong	Renzidong	Longdan	Gongwangling	Extant
Archaic	370																
St Vallier	116	370															
Chilhac	78	316	370														
Dmanisi	92	298	332	370													
Xiaochangliang	70	288	326	316	370												
Yuxian	76	286	324	310	344	370											
Tuozidong	100	266	300	290	316	314	370										
Yuanmou	92	266	304	294	316	314	298	370									
Mohui	80	262	300	286	308	302	294	306	370								
Dadong	72	246	284	274	292	286	286	290	326	370							
Juyuandong	84	242	276	262	284	278	266	282	318	302	370						
Longgupo	110	232	266	252	270	268	280	288	300	292	288	370					
Longgudong	102	236	278	268	286	276	264	280	320	300	288	278	370				
Renzidong	96	246	288	278	296	286	282	274	294	282	258	280	268	370			
Longdan	106	264	294	284	306	300	280	284	280	260	256	254	250	268	370		
Gongwangling	86	260	298	288	306	296	288	288	284	272	276	258	270	264	282	370	
Extant	0	254	292	278	300	294	270	278	290	298	285	260	268	274	264	284	370

**Table 2**

Biochronologically sequenced large mammal faunas based on B-R Antiquity Coefficient and extinct rate.

Sequenced faunas	B-R Antiquity Coefficient	Extinct taxa	Total taxa	Extinct rate
Longdan	106	26	26	100.00%
St Vallier	116	28	31	90.30%
Chilhac	78	12	12	100.00%
Yuxian	76	10	11	90.90%
Longgupo	110	32	42	76.20%
Tuozidong	100	19	25	76.00%
Renzidong	96	23	33	69.70%
Dmanisi	92	17	19	89.50%
Yuanmou	92	17	21	80.95%
Gongwangling	86	21	26	80.80%
Juyuandong	84	22	35	62.90%
Mohui	80	14	24	58.30%
Longgudong	102	18	36	50.00%
Dadong	72	15	31	48.40%
Xiaochangliang	70	5	10	50.00%

of forest and woodland in the Tuozidong area in the Early Pleistocene. Open grassland taxa are *P. perrieri*, *A. arvernensis*, *H. (Proboscoidipparion) sinense*, *E. huanghoensis*, *Meg. guangxiensis*, *G. sinensis*, and *Le. (Smertiobos) cf. crassus*. They indicate the existence of certain areas of open grassland around Tuozidong in the Early Pleistocene. In addition, *Sinocastor* sp. was not included in the analyses as a small mammal, but it might prefer streams nearby to build their nests. *Su. lydekkeri* might prefer some swamps to play with or search for food.

Such an environment, with a considerable range of forests and woodland surrounded by some open grassland with some streams nearby in the early Pleistocene, offers an ideal habitat for human settlements.

## 5. Discussion

The Tuozidong fauna has some typical Chinese or East Asian forms such as *Sinocastor* sp., *N. sinensis*, *Eirictis* sp., *Me. pleistocaenica*, *L. shansius*, *St. cf. preorientalis*, *H. (Proboscoidipparion) sinense*, *E. huanghoensis*, *Met. cf. capreolinus*, *C. ultimus*, *Ax. shansius jiangningensis*, *Ce. (Sika) cf. grayi*, *Ce. (Sika) cf. magnus*, *Meg. guangxiensis*, *G. sinensis*, and *Le. (Smertiobos) cf. crassus*. Among these forms, some taxa are endemic in China, such as *Eirictis* sp., *St. cf. preorientalis*, *H. (Proboscoidipparion) sinense*, *Met. cf. capreolinus*, *C. ultimus*, *Ax. shansius jiangningensis*, *Ce. (Sika) cf. grayi*, *Ce. (Sika) cf. magnus*, and *Meg. guangxiensis*. They probably adapted to Chinese environments for quite a long period and evolved into such specialized forms.

It is remarkable, on the other hand, that the following taxa from Tuozidong are comparable to their European counterparts: *M. peii*, *N. sinensis*, *Meles* sp., *Ursus* sp., *P. perrieri*, *L. shansius*, *A. arvernensis*, *E. huanghoensis*, *Su. lydekkeri*, and *G. sinensis* (Figs. 3 and 4).

*M. peii* was established by Fang et al. (2002) based on a nearly complete mandible, a mandibular fragment and some isolated teeth from Tuozidong. The materials show that the mandibles are particularly robust compared to the other prehistoric and extant macaques from China (Fang et al., 2002; Fang and Gu, 2007). The excavation in 2007 yielded a right maxillary fragment of the species (Fig. 4A), and it is logical to regard the specimen as being in the same population. Macaca is present at Longgupo, Longgudong, Dadong and Mohui as *Macaca* sp. It is present at Renzidong and Longdan as *Macaca anderssoni*. Other Early Pleistocene macaques from China include *Macaca robustus*, *Macaca youngi* and *Macaca jiangchuanensis*. It is true that the macaque materials available are limited to some broken skulls and incomplete dentitions, and

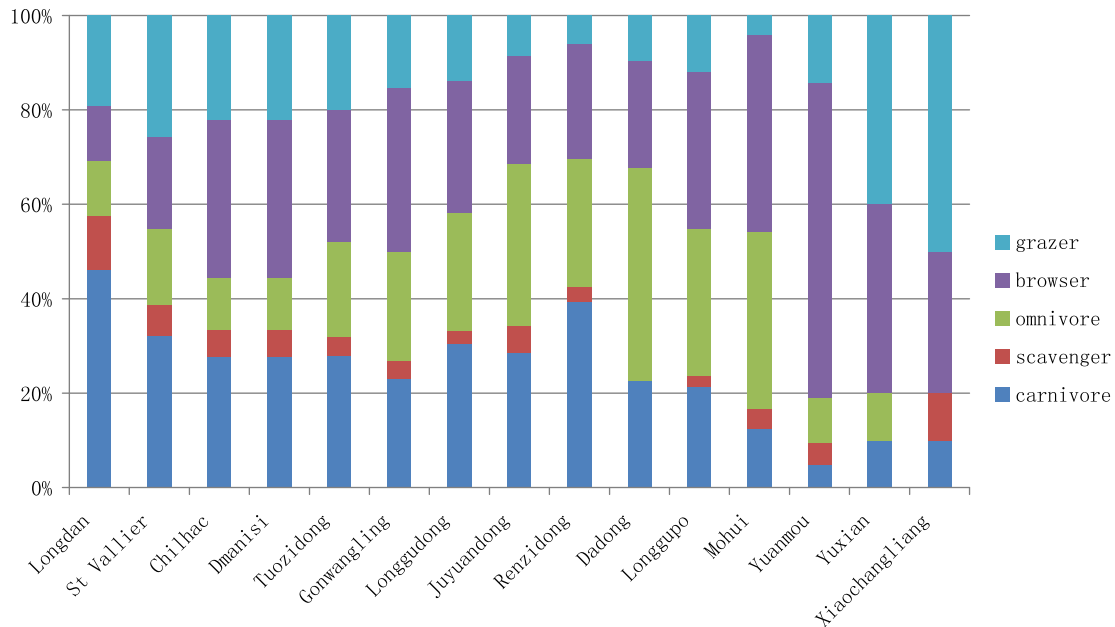


Fig. 2. Comparison of ecological composition between Tuozidong fauna and selected Eurasian Early Pleistocene faunas.

mostly isolated teeth. It is not surprising that these materials from different sites show some distinguishable morphological variations. Delson (2004) suggested that all European fossil macaque populations could be referred to one of several temporal subspecies of *Macaca sylvanus*. This hypothesis may also be applicable to Asian macaques. According to fossil macaque records (Jablonski, 2002), European macaques were probably derived from African Late Miocene *Macaca libyca*, and Asian macaques probably from European Early to middle Pliocene *Macaca sylvanus prisca*. The presence of macaques in both Asia and Europe as well as in Africa implies that macaques dispersed to these continents before the Early Pleistocene and the environments were already available for their colonization, and the environmental barriers in the middle of their dispersal routes were not unconquerable for macaques.

Tedford and Qiu (1991) agreed with Viret (1954), and Soria and Aguirre (1976), that Chinese *N. sinensis* and European *Nyctereutes megastoides* are morphometrically closely allied and they could represent the extremes of the zoogeographic range of a single taxon. The *N. sinensis* from Tuozidong (Fig. 3F) is morphometrically very similar to *N. sinensis* from both Nihewan and Yushe, as well as to *N. megastoides* from Perrier, Senèze and Villaroya. Although the former *Nyctereutes megastoides vulpinus* from Saint Vallier was regarded as *Nyctereutes vulpinus* by Monguillon et al. (2004), *N. megastoides* is still confirmed as present in the fauna from Saint Vallier (Argant, 2004). It is evident that certain Chinese and European *Nyctereutes* do have some close affinities.

*L. shansius* from Tuozidong (Fig. 3C) is very similar to that from Nihewan (Teilhard de Chardin and Piveteau, 1930), Yushe and Loc. 18 of Zhoukoudian (Teilhard de Chardin, 1940) described by Teilhard de Chardin and Leroy (1945), and that from Longdan (Qiu et al., 2004). It has some morphological differences that distinguish it from European *Lynx issodorensis*. Kurtén and Wendelin (1984) considered that the Chinese form was a subspecies of its European counterpart.

*Meles* sp. from Tuozidong (Fig. 3B) is comparable to *Meles thorali* from Saint Vallier (Argant, 2004). Based on their morphology, they are evidently not the same species, but they have close affinities. The same applies to *Ursus* sp. from Tuozidong (Fig. 3A) which is morphometrically close to European *Ursus minimus*.

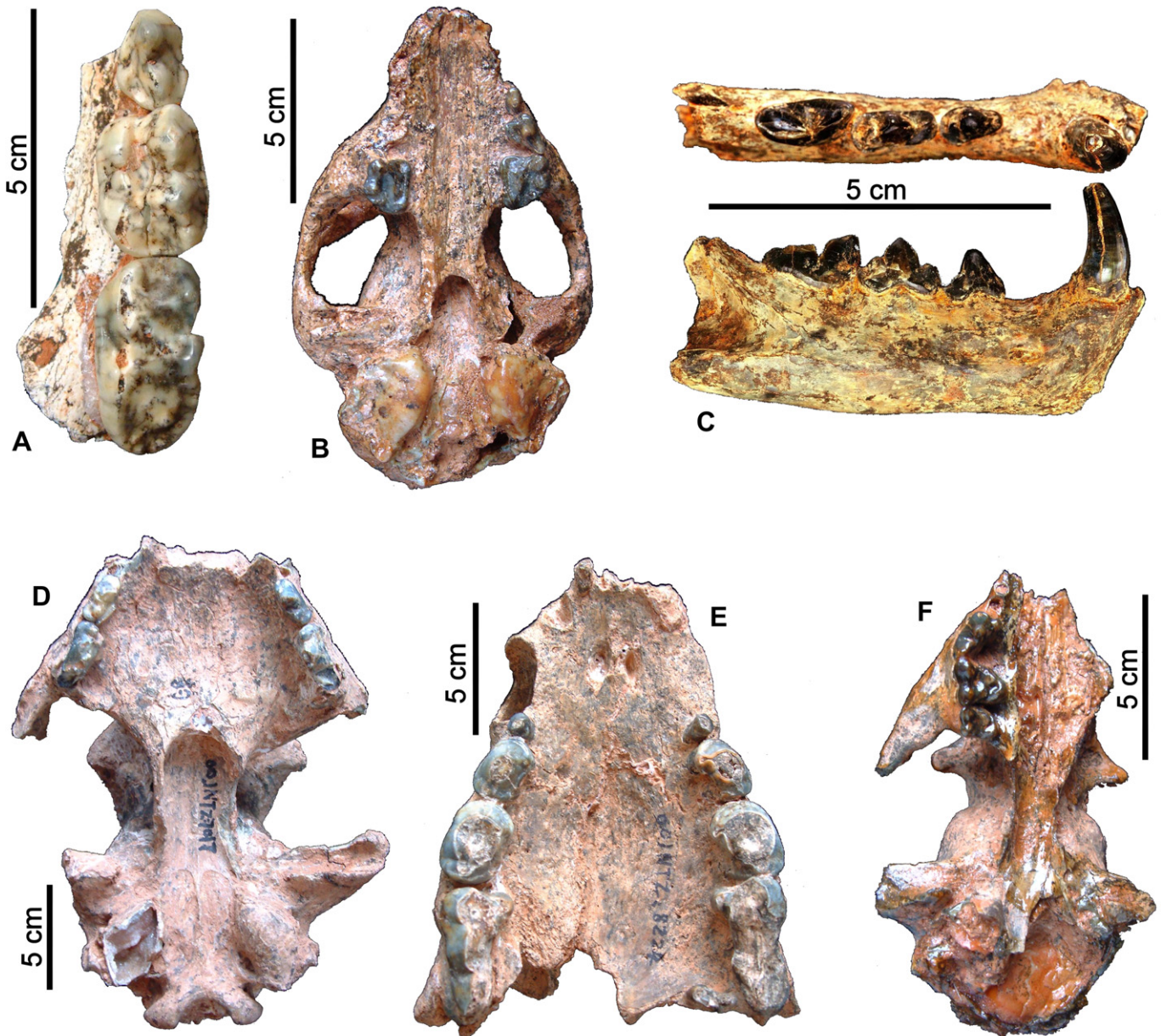
*P. perrieri* from Tuozidong (Fig. 3E) is morphometrically very similar to that from Saint Vallier (Viret, 1954). The species is common in Europe and is also present at Dmanisi. *A. arvernensis* from Tuozidong (Fig. 3D) is morphometrically very similar to that from Etouaires (Schaub, 1949). The presence of such taxa in East Asia and West Europe indicates that fauna exchange existed during the Early Pleistocene, and environmental barriers were not unconquerable for such taxa.

*S. kirchbergensis* from Tuozidong (Fig. 4B) is the third taxon of European form in the fauna. It was originally found in Europe, but it has been found in many Early to Middle Pleistocene sites in northeastern, northern, and eastern China.

*E. huanghoensis* from Tuozidong (Fig. 4C) is a very large horse. Its dental morphology is comparable to that of European *Equus stenonis*, but its size is evidently larger (Dong and Fang, 2005). *E. stenonis* is present in many European Early Pleistocene sites (Eisenmann, 1980, 2004), but it is also present in some Chinese Early Pleistocene sites. Deng and Xue (1999) supposed that the species could be considered to have originated in China and then dispersed to Europe in the Early Pleistocene.

*Su. lydekkeri* from Tuozidong (Fig. 4D) is a typical Early and Middle Pleistocene suid in northern China. Its southern counterpart is *Sus peii*, and the European counterpart is *Sus strozzi*. Actually, the morphology of these three species does show some differences, but their common traits are also sufficiently numerous that these species can either be interpreted as three subspecies of a single one, or as three independent but closely related ones (Dong, 2008).

*G. sinensis* from Tuozidong (Fig. 4E) is a common taxon of northern China derived probably from the Pliocene *Gazella paotehensis*. Several gazelle species were found in China from the Late Miocene to Pleistocene, e.g. *Gazella gaudryi*, *G. paotehensis*, *Gazella dorcadoides*, *G. sinensis*, *Gazella blacki*, *Gazella kueitensis*, *Gazella paragutturosa* (Wang and Wu, 1979). In eastern Asia, the genus has declined to a single extant species, *Gazella subgutturosa*, which ranges from northwestern part of China to central Asia (Wang, 2003). However, the genus has several extant species in Africa and the Arabian Peninsula (Nowak and Paradiso, 1983). It seems that *Gazella's* main range shifted from East Asia to the Middle East and Africa in the Pleistocene.



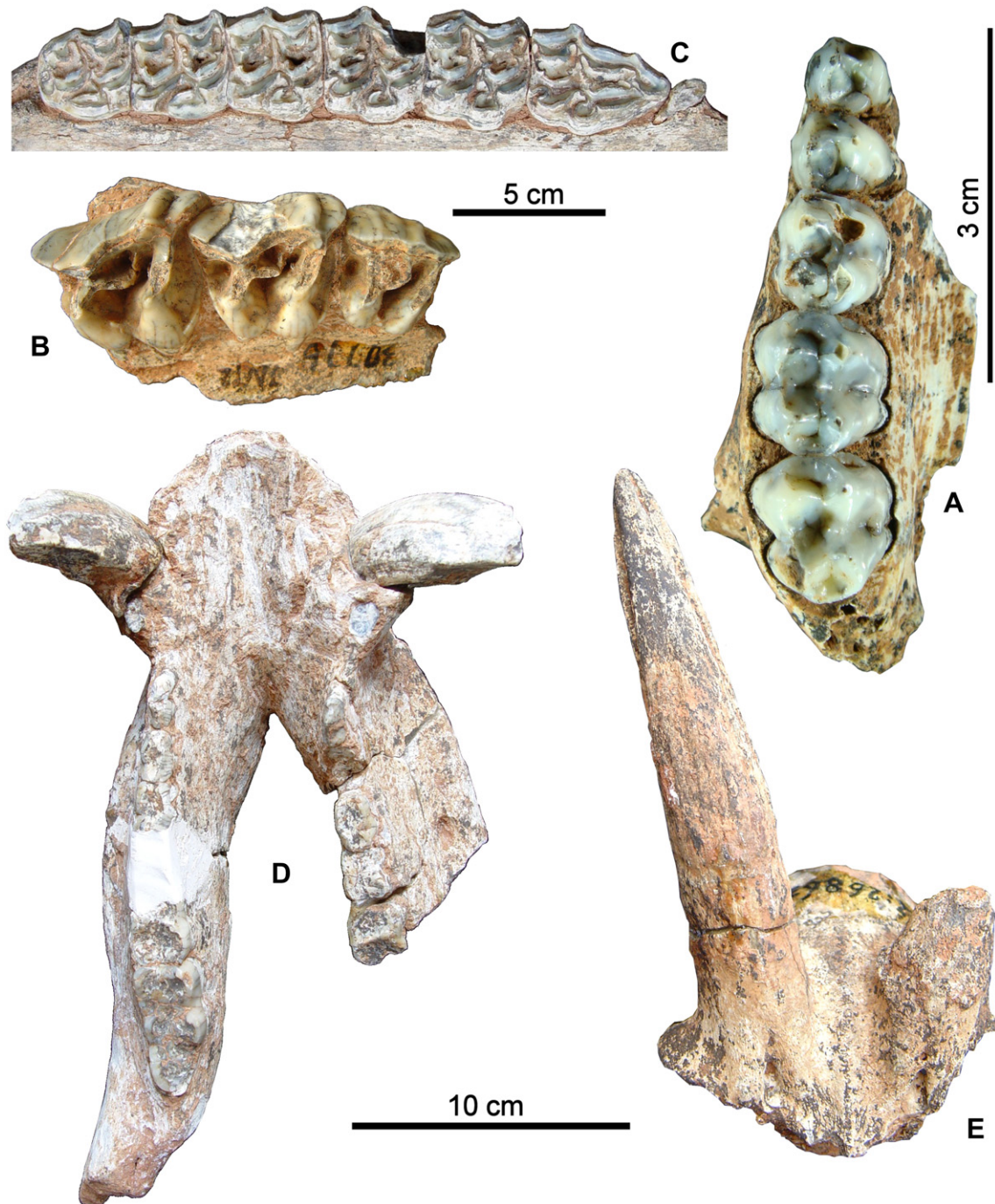
**Fig. 3.** Carnivores from Tuozidong identical or comparable to their European counterparts. A. *Ursus* sp., left maxillary fragment (JNTZ12488); B. *Meles* sp., a nearly complete skull (JNTZ1323); C. *Lynx shansius*, right incomplete mandibular body (JNTZ14509); D. *Acinonyx arvensensis*, incomplete skull (JNTZ7017); E. *Pachycrocuta perrieri*, incomplete upper jaw (JNTZ8224); F. *Nyctereutes sinensis*, incomplete skull (JNTZ7571).

Some forms preferred to stay in certain areas and adapted themselves to the local environments to form endemic taxa, but others preferred to explore new territories and to migrate as far as possible and to colonize widely. Based on the large mammals from Tuozidong, roughly half of the taxa were good migrators. They migrated because they were probably very curious or active and more interested in new habitats. Probably they were obliged to migrate because of their population expansion, or because they could not compete successfully with their food and habitat rivals, or due to natural disasters such as earthquakes, fires, and floods. The presence of some common taxa in Eastern Asia and Western Europe indicates that the geographic and climatic barriers between Eurasia were not strong enough to stop the fauna exchanges between two continents; the same should be true for early humans' migration. *Gazella*'s presence in Eurasia and Africa indicates that

the environmental barriers between Africa and Eurasia have become conquerable since the Early Pleistocene for certain taxa, including early humans.

The widely accepted earliest presence of humans in Eurasia are found at Dmanisi of Georgia (Gabunia and Vekua, 1995; Gabunia et al., 2000) and at Yuanmou in southern China (Qian et al., 1991), both dated 1.7 Ma. Consequently, the artifacts from Dmanisi are accepted as the earliest Paleolithic industry found in Eurasia. The artifacts earlier than 1.7 Ma from other Eurasian sites remain as controversial Paleolithic industries or as putative candidates for the earliest representatives.

The artifacts from the Longgupo Site were firstly reported in 1991 (Huang et al., 1991), confirmed later and dated as 1.9 Ma (Huang et al., 1995). The artifacts collected in later years' excavations were described recently (Boëda and Hou, 2011), and their ages



**Fig. 4.** Primates and ungulates from Tuozidong identical or comparable to their European counterparts. A. *Macaca peii*, right maxillary fragment (V15446); B. *Stephanorhinus kirchbergensis*, right maxillary fragment (JNTZ30776); C. *Equus huanghoensis*, right cheek teeth row (JNTZ6403); D. *Sus lydekkeri*, incomplete lower jaw (JNTZ26473); E. *Gazella sinensis*, frontals with horn cores (JNTZ8224).

were estimated as the Early Pleistocene, earlier than the Olduvai episode (Boëda et al., 2011), around 2 Ma. The artifacts from Longgudong were described some years ago (Li, 2004) and the age estimated at 2.15 Ma–2.42 Ma (Gao and Cheng, 2004). However, recently the age was estimated as later than that of Longgupo and Mohui, earlier than that of Dadong, between 1.6 Ma and 1.8 Ma (Jin et al., 2009a). Detailed description of the artifacts from Renzidong was published recently (Zhang et al., 2009), and the age was estimated at 2 Ma (Jin et al., 2009b). The single core tool made of granular quartzite with partial cortex intact from Yuxian dated

3 Ma (Tang et al., 2000) is still questioned for its stratigraphic provenance and dating. The artifacts from Longgupo and Renzidong remain therefore as putative candidates for the earliest Paleolithic industry in China (Dong, 2006). The “convincing examples of intentionally flaked stone” found in a sandstone/conglomerate in the Soan Valley at Riwat, Pakistan, and dated to a minimum of 1.9 Ma (Dennell, 2003) were considered as the earliest Paleolithic industry in southern Asia (Larick and Ciochon, 1996).

The purported Oldowan artifacts from Europe were summarized by Bonifay (2002). Those around or earlier than 2 Ma were from

St-Eble and Chilhac in Massif Central and Sept-Fonts in Dordogne of France, Grenade of Spain, Tetoiu of Romania (Bonifay, 2002). A quartz artifact was also reported from St-Vallier in Massif Central by Bourdier in 1961–1962, but it was lost and its artifact status was subject to criticism (Fauvre and Guérin, 2004). Although questioned and even considered as geofacts or tephrofacts (e.g. Raynal et al., 1996; Raynal and Magoga, 2000), the purported artifacts from St-Eble and Chilhac can be considered as putative candidates for the earliest Paleolithic industry in Europe.

The Ubeidiya Site in Israel yielded many Paleolithic artifacts (Early Acheulian) and a few early human materials (Bar-Yosef and Tchernov, 1986). The site is very interesting for its geographic location between Eurasia and Africa, and it might indicate the earliest migration age of early humans out of Africa. The site was originally dated as between 2.6 Ma and 1.6 Ma (Repenning and Fejfar, 1982) but revised later by general consensus as 1.4 Ma (Tchernov et al., 1986). If Paleolithic industries in East and South Asia as well as West Europe can be dated to as early as 1.9–2 Ma, the age of Ubeidiya fauna can be considered as equivalent to or earlier than 2 Ma. Otherwise, there should be some other hidden sites in or around Israel with an age equivalent to or earlier than 2 Ma.

Based on the faunal analysis and comparison, suitable environments were already available for human occupation in Eurasia around 2 Ma. The common taxa or closest relatives found in the Early Pleistocene sites of East Asia and West Europe, and the habitat center shift of *Gazella*, indicate that the environmental barriers for large mammal migration were conquerable in the Early Pleistocene. It should be the same for early humans. The earliest Paleolithic industry was found in the Gona region of Afar, Ethiopia, East Africa, and dated to 2.6 Ma (Millikan, 2004). The distance between Afar and the Horn of Africa is about 300 km, a distance that many African mammals, particularly ungulates, travel every year for food with seasonal change. The distance between Afar and Levantine corridor is about 2500 km, a rather spectacular and sportive distance for terrestrial mammals to migrate annually. It is remarkable that modern reindeer travel such distances every year scanning Holarctic tundra and taiga for their food. As a highly nomadic species, “reindeer may travel 5000 km/3000 miles in a year, the longest documented movements of any terrestrial mammal. In addition, most populations undertake extensive migrations in the spring and fall, travelling. During these migrations, herds move at a rate of 19–55 kilometers/11–33 miles per day.” “Reindeer are excellent swimmers, and will readily cross large rivers or lakes” (Henttonen and Tikhonov, 2008).

The distance from Afar via the Levantine corridor to Riwayat is about 6300 km, and that to Longgupo and Renzidong about 12 000 km. Supposing that an early human population could travel 10 km a year, they would need 630 years to migrate from Afar to Riwayat, and 1200 years to Longgupo or Renzidong. If, more prudently, suppose the population expanded 1 km only per generation and a generation takes 15 years, it would need 94.5 ky and 180 ky to move the same distances. The temporal interval from the earliest African Paleolithic industry of 2.6 Ma to the supposed earliest human settlements in Eurasia at 2 Ma is quite sufficient for a human population to migrate from Afar to East Asia or West Europe. The dynamics of early human movement out of Africa could be Vrba's Turnover Pulse, or the Sahara Pump. Episodes of relatively high faunal turnover in East Africa occurred in the intervals 3.4–3.2, 2.8–2.6, 2.4–2.2, and 2.0–1.8 Ma (Bobé and Behrensmeyer, 2004), with a minimum interval of 200 ky. That is enough for early humans to migrate out Africa into Eurasia, particularly with the turnover interval of 2.4–2.2 Ma. If an early human population could not migrate from East Africa to Eurasia before 1.7 Ma, there must have been some serious environment barriers, unconquerable for early humans, from 2.6 Ma to 1.7 Ma.

Future research should be oriented to investigate potential barriers during this time interval.

## 6. Conclusions

The Tuozidong fauna is similar to that of Yuanmou and Gongwangling, the faunas associated with accepted early human materials. The environments at Tuozidong were suitable for habitation by early humans. The Tuozidong fauna is also similar in some degree to that of Saint Vallier and Chilhac in West Europe. The common taxa or closest relatives in Tuozidong fauna of East Asia as well as Saint Vallier and Chilhac faunas of West Europe indicates the existence of faunal exchanges between East Asia and West Europe. The environment barriers between Eurasian continents were not unconquerable in the early Pleistocene for mammal migrations. The shift of gazelle's main range from East Asia to Middle East and Africa in the Pleistocene might indicate the environment barriers were conquerable for some mammals to migrate across continents in those periods. The earliest tool-makers of 2.6 Ma in East Africa had the capability to disperse or migrate to Eurasia within relatively short periods, and the putative Paleolithic industries from Longgupo and Renzidong in East Asia, those from Riwayat in South Asia and probably those from St Eble and Chilhac in West Europe might be witnesses of earliest human settlements in Eurasia around 1.9–2 Ma. If early humans could not disperse from Africa to Eurasia before 1.7 Ma, there should be some unconquerable environmental barriers between Africa and Eurasia, identification of which should be aimed at in future research.

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## Appendix. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.quaint.2012.01.014.

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