

Pliocene and Early Pleistocene Primitive Mammoths of Northern China: Their revised taxonomy, biostratigraphy and evolution

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Abstract

Primitive mammoth remains from the Pliocene and Lower Pleistocene of northern China are examined taxonomically and biostratigraphically. The taxonomy of the remains has been greatly confused in previous studies, but our revision reveals that three species such as *Mammuthus rumanus*, *M. meridionalis* and *M. trogontherii* are recognized in the remains. The recognition of the three species is comparable with the revised classification of the primitive mammoths recently proposed for European and Siberian remains. Among the three species, *M. rumanus* and *M. meridionalis* occur in the Pliocene sediments paleomagnetically dated as ca. 3.4-2.8 Ma and ca. 2.6-1.8 Ma, respectively. The biostratigraphic range of the remaining species, *M. trogontherii*, is determined more accurately to be 1.66 to 1.1 Ma in the Early Pleistocene, by referring to the results of the paleomagnetic measurements. On the basis of the taxonomic and biostratigraphic conclusions, we briefly discuss the evolution of the primitive mammoths in northern China, and their migration to and from the same area.

Key-words : Pliocene, Early Pleistocene, Mammoth, Taxonomy, Biostratigraphy, Evolution, northern China

1. Introduction

The primitive mammoths described here can be regarded as the direct ancestors of the woolly mammoth, *Mammuthus primigenius*, which is one of the most popular prehistoric animals. All the mammoths constitute the genus *Mammuthus*, which belong to the true elephant family, Elephantidae, with high-crowned elasmodont cheek teeth. Such cheek teeth are frequently found as fossils, and generally considered as the most important part for specific and generic distinction except well-preserved skulls which

are rarely found. However, it is not easy to distinguish the cheek teeth of the primitive mammoths from those of *Palaeoloxodon*, a different genus of Elephantidae. Thus there have been considerable confusions in the classification of fossil cheek teeth of elephantids from China among some previous paleontologists.

The first scientific note on an elephantid cheek tooth from China appeared in Busk (1868), who identified it as "*Elephas armeniacus*" (= *Mammuthus trogontherii*). In the first comprehensive work on Chinese proboscidean fossils by Hopwood (1935), however, he assigned the cheek tooth to *Palaeoloxodon* cf. *namadicus*. On the other hand, he

first recognized a primitive mammoth cheek tooth in the fossil collections studied, and described it under the name of *Archidiskodon* cf. *planifrons* (see p.69 of the present paper). The generic name of *Archidiskodon* was generally adopted to the primitive mammoths at that time, but is now synonymized with *Mammuthus*. Two years later, several primitive mammoth cheek teeth from the Yushe Basin in northern China were described by Teilhard de Chardin and Trassaert (1937) who classified them into the two species, *A. planifrons* and *A. tokunagai*. The latter species name, *tokunagai*, is currently considered as a synonym of *naumanni* which is adopted to one of the typical species of *Palaeoloxodon*.

Subsequently, cheek teeth assigned to *Archidiskodon* were reported from several localities in northern China (Chow, 1957, 1961; Chow and Chow, 1959, 1965). Summarizing their works on Chinese proboscidean fossils, Chow and Chang (1974) published a monograph, in which they described three species, *Archidiskodon planifrons*, *A. meridionalis* and *Mammuthus trogontherii* as the primitive mammoths of China. Their definition of each species is partly doubtful, because the cheek teeth identified as *A. meridionalis* cannot be allocated to *Mammuthus*, but to *Palaeoloxodon* in our view (Pls. 23 and 24 of the monograph). Additionally Jin (1983) described a new species of *Archidiskodon*, *A. weifangensis* from northern China, but we also believe that this species belongs to *Palaeoloxodon*.

The classification of the primitive mammoths from China was greatly confused by Zhang and Zong (1983). They abandoned the distinction of *Mammuthus* from *Palaeoloxodon* by the cheek teeth, and allocated all the primitive mammoths so far reported to *Palaeoloxodon*. We believe that the primitive mammoths and *Palaeoloxodon* apparently belong to different lineages from each other, and thus in China, a revised classification has been requested for the primitive mammoths in relation to *Palaeoloxodon* since Zhang and Zong (1983).

Recently studies on Eurasian mammoths have shown a remarkable advancement on their taxonomy and evolution (Lister, 1996; Lister and Sher, 2001; Lister and van Essen, 2003). In their papers, however, the information on mammoth fossils from China has not been used, and thus we consider that the addition of the information from China is necessary for understanding the Pan-Eurasian mammoth evolution. In this connection, a part of the information from China was preliminarily presented in Lister *et al.* (2005) and Wei and Lister (2005).

In the present paper, we attempt to revise the taxonomy of the Pliocene and Early Pleistocene primitive mammoths from China in the light of the recent knowledge on the taxonomy of the genus *Mammuthus*. We also attempt to

arrange the fossil records in the reliable chronological framework obtained mainly by paleomagnetic methods and to clarify the biostratigraphic distribution of the mammoths in China. On the basis of the revised taxonomy and biostratigraphy, we discuss the mammoth evolution in China since the Pliocene.

2. Plio-Pleistocene boundary

In China, the Plio-Pleistocene boundary is generally placed at the Gauss-Matuyama geomagnetic polarity boundary (ca. 2.6 Ma). Thus the Early Pleistocene ranges from ca. 2.6 Ma to ca. 0.8 Ma. In the present paper, however, we adopt one of the most recent geological time tables given by Gradstein *et al.* (2004), where the boundary is determined at ca. 1.8 Ma, and the Early Pleistocene covers the period from ca. 1.8 Ma to ca. 0.8 Ma (Fig. 6). In order to avoid chronological confusion, we use the term Early Pleistocene with quotation marks (“Early Pleistocene”) for the Early Pleistocene in Chinese general sense in the subsequent chapters of the present paper. Thus the onset of the “Early Pleistocene” is ca. 2.6 Ma, but that of the Early Pleistocene is ca. 1.8 Ma.

3. Fossil localities and their ages

The primitive mammoth remains considered in the present paper occur from the localities shown in Fig. 1. The geological background of each locality is briefly given below. From a chronological viewpoint, the localities are divided into two categories, as paleomagnetically dated ones and other ones.

3.1 Paleomagnetically dated localities

Localities in the Nihewan Basin (NB in Fig. 1) —

Plio-Pleistocene fluvio-lacustrine sediments with abundant mammalian fossils are distributed in the Nihewan Basin about 150km west-north-west of Beijing. Barbour (1924) first noticed the sediments geologically, and referred to them as the “Nihowan (Nihewan) beds”. The first monographic work on the mammalian fossils was published by Teilhard de Chardin and Piveteau (1930). Furthermore, Breuil (1935) first noticed the occurrence of a “stone artifact” from the basin. After these studies, many papers have been published on stratigraphy, paleontology, archaeology, chronology, sedimentology, tectonics and paleoenvironments of the sediments mainly by Chinese authors, because they have recognized the importance of the sediments for clarifying not only Plio-Pleistocene geohistory but also paleolithic human history in northern China.

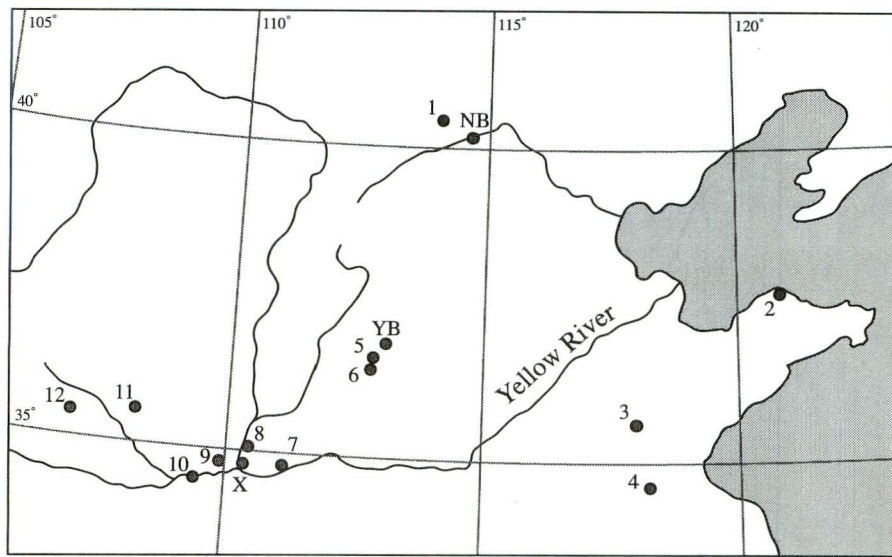


Fig. 1 Fossil localities yielding the mammoth remains described or discussed in the present paper. NB: Nihewan Basin, X: Xihoudu, YB: Yushe Basin. 1: Tianzhen, 2: Penglai, 3: Mengyin, 4: Tanchen, 5: Qinxian, 6: Tunliu, 7: Pinglu, 8: Linyi, 9: Dali, 10: Weinan, 11: Heshui, 12: Pingliang.

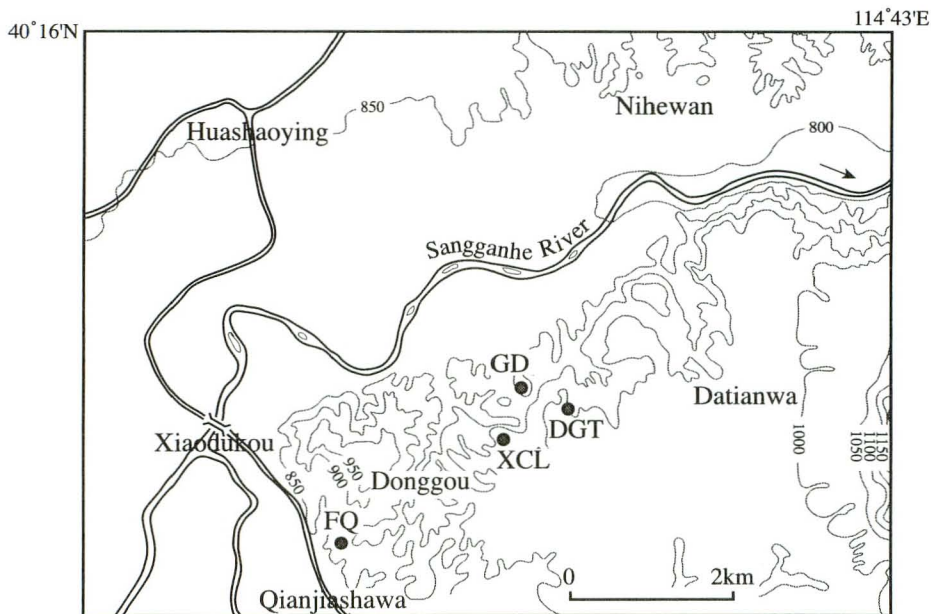


Fig. 2 Fossil localities in the Nihewan Basin. DGT: Donggutuo site, FQ: Fossil locality at Qianjiashawa, GD: Goudi site in Majuangou Gorge, XCL: Xiaochangliang site.

As regards the subdivision of the sediments, many authors have proposed different schemes. In the present paper, however, we follow the subdivision of Wei (1997), because it is one of the most recent synthetic works on the stratigraphy of the sediments, and shows the stratigraphic positions of many archaeological sites in the basin. He

divided them into the Nihewan Formation (lacustrine mud and sand beds of the “Early Pleistocene”), the Xiaodukou Formation (lacustrine mud and sand beds of the Middle Pleistocene), the Xujiayao Formation (lacustrine mud and sand beds in its lower part, and loess in its upper part; Late Pleistocene), the Shiyu Formation (Late Pleistocene higher

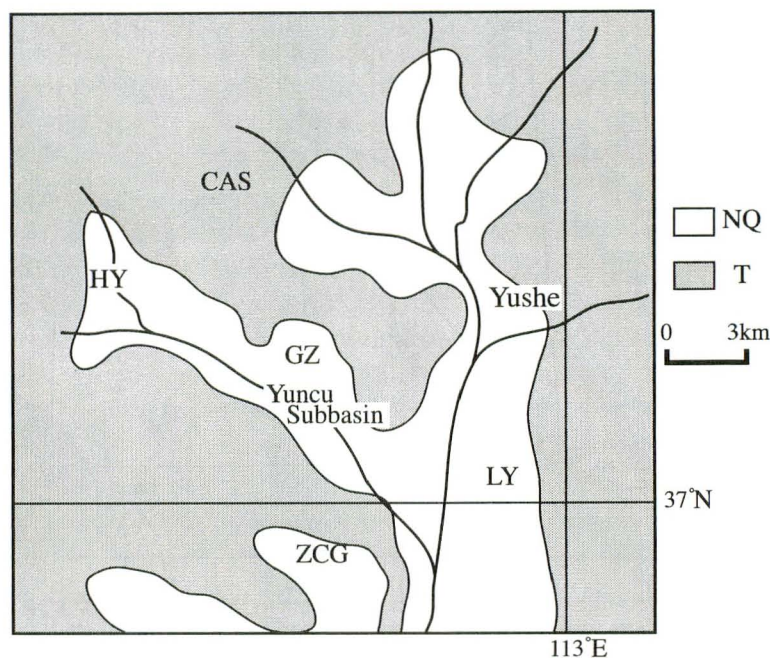


Fig. 3 Fossil localities in the Yushe Basin (NQ: Neogene-Quaternary sediments, T: Triassic sedimentary rocks). CAS: Caiashan, GZ: Gaozhuangcun, HY: Haiyan, LY: Liyucun, ZCG: Zhangcungou.

terrace deposits), and the Hutouliang Formation (Late Pleistocene lower terrace deposits), in ascending order.

The mammoth teeth discussed in the present paper occurred from four localities (Fig. 2), of which three are archaeological sites yielding “Early Pleistocene” stone artifacts (Goudi, Xiaochangliang and Donggutuo).

The Goudi, Xiaochangliang and Donggutuo sites are assigned to the middle, upper and uppermost parts of the “Early Pleistocene” Nihewan Formation of Wei (1997), respectively. Recently, Zhu *et al.* (2001, 2003, 2004) reported the results of the detailed paleomagnetic studies on the sediments at the sites. Among the studies, Zhu *et al.* (2004) determined paleomagnetically the age of the artifact horizon of the Goudi site in Majiangou Gorge (MJG-III) as 1.66 Ma, where the mammoth teeth were obtained (Wei *et al.*, 2003). The site was recently described by Gao *et al.* (2005). On the other hand, Zhu *et al.* (2001) dated the artifact horizon of the Xiaochangliang site as 1.36 Ma. The mammoth tooth originally described as *Palaeoloxodon* sp. by Tang *et al.* (1995) was obtained from the same horizon. Furthermore, Zhu *et al.* (2003) reported the age of the artifact horizon of the Donggutuo site as 1.1 Ma, which is also considered to be the age of the mammoth molar from this site (Wei *et al.*, 1985).

In the remaining locality, Qianjiashawa, the mammoth molar was collected from a gravel bed of the lower part of the above-mentioned Nihewan Formation (personal

communication from Wei Q.). Judging from Fig. 4 of Yuan *et al.* (1996), the locality roughly corresponds to the lower part of the section at “Donggou” (Fig. 2). In the same figure, the succession of magnetic polarity measured in the section shows that the lower part of the Nihewan Formation roughly ranges from 2.6 Ma to 1.8 Ma.

Localities in the Yushe Basin (YB in Fig. 1) —

The fluvio-lacustrine sediments ranging from the Late Miocene to “Early Pleistocene” fill the Yushe Basin in the southeastern part of Shanxi Province. The sediments are collectively called the Yushe Group. The studies on stratigraphy and rich mammalian fossils of the group were initiated by Teilhard de Chardin and Young (1933), and Licent and Trassaert (1935). Subsequently, the studies have been continued by many authors. An outstanding development was achieved by American and Chinese scientists in the late 1980’s and 1990’s (Tedford *et al.* 1991; Flynn *et al.*, 1991, 1997 etc.). Their studies are characterized by the reliable chronological framework based on detailed paleomagnetic measurements. We adopt their chronology in the present paper in order to determine the chronological positions of the mammoth remains described and discussed herein.

The Yushe Basin is often divided into several subbasins owing to its complicate outline (Fig. 3). Among them, the Yuncu subbasin bears a typical sequence of the Yushe Group. Qiu *et al.* (1987) described the following

sequence in the subbasin in ascending order. The lowermost Mahui Formation consists of gravel, sand and mud. The second Gaozhuang Formation consists of alternating beds of sand and mud. The third Mazegou Formation is composed mainly of sand beds. The topmost Haiyan Formation consists of sand and mud. On the basis of Figs. 3 and 5 in Tedford *et al.* (1991), the Mahui, Gaozhuang, Mazegou and Haiyan Formations are paleomagnetically dated as 5.9-5.4 Ma, 5.4-4.0 Ma, 3.4-2.8 Ma and 2.5-1.9 Ma, respectively.

The mammoth molar of Tianjin Natural History Museum (THP18.906) was obtained from the upper part of the Mazegou Formation at Liyucun (Loc. 20*) in Yushe County (personal communication from Chen G. F., Zheng S. H. and Wu W. Y.). The molars of the same museum (THP10.464, 10.461, 10.459, 10.460, 10.462) belong to the same individual, and were collected from the Haiyan Formation at Haiyan (Loc. 6*). The description of Teilhard de Chardin and Trassaert (1937) and the records preserved in the museum indicate that the other molars of the same museum (THP 31.132, 30.803, 18.898 and 10.456) were collected from Caiaoshan (Loc. 34*), Liyucun (Loc. 20*), Gaozhuangcun (Loc. 17*) and Zhangcungou (Loc. 2*). The description and records on their localities are, however, quite doubtful. For example, fossiliferous sediments are completely absent at Caiaoshan (Fig. 3; personal communication from Chen G. F.). Moreover THP31.132 undoubtedly belongs to the same individual as THP30.803, but it is recorded that the former and latter were collected from Caiaoshan and Liyucun respectively. Thus it is probable that the molars were not collected from the sediments, but were obtained from some drugstores or from local people of Yushe County.

Xihoudu (X in Fig. 1) —

Xihoudu (Hsihoutu) in Ruicheng Country, Shanxi Province, is a well known village among Chinese archaeologists and paleoanthropologists, because a paleolithic archaeological site yielding "Early Pleistocene" stone artifacts is situated there. Chia and Wang (1978) divided the sediments exposed at the site into five formations, namely the early Pliocene Bahe Formation consisting of mudstone and conglomerate, the late Pliocene Lantian Formation consisting of clay and gravel beds, the "Early Pleistocene" Xihoudu Formation consisting of sand beds, the Middle Pleistocene Xiehu Formation consisting of loess-like sediments with paleosol beds, and the Late Pleistocene Malan Formation (loess), in ascending order. The artifacts in association with mammalian fossils were obtained from the

Xihoudu Formation. The fossils include the mammoth mandible and molars described later in the present paper. Recently, Zhu *et al.* (2003) conducted a detailed paleomagnetic study at this site, and determined the age of the artifact layer in the formation as 1.27 Ma, although Jia (1985) dated the layer as about 1.8 Ma based on preliminary paleomagnetic measurements. Here we adopt the age of Zhu *et al.* (2003), because it is more reliable than that of Jia (1985) judging from their sampling and measuring techniques.

3.2 Other localities

Tianzhen (1 in Fig. 1) —

Qiu *et al.* (2002) described remains of the extinct hyrax, *Postschizotherium intermedium*, from the locality called 81018 in Tianzhen Country, Shanxi Province. From the same locality, they listed other larger mammals including *Agriotherium* sp., *Plesiohipparion houfense* and *Equus sanmeniensis*. The two unnumbered mammoth cheek teeth described in the present paper (p.80-81) were also obtained from this locality. On the basis of the faunal characteristics, Qiu *et al.* (2002) considered the age of the fossil-bearing sediments of the locality as the "Early Pleistocene" ranging from 2.6 to 1.8 Ma, although other chronological evidences including paleomagnetic data were not given by them.

Penglai (2 in Fig. 1) —

The two mammoth molars of Shandong Provincial Museum (77004 and 77005) described in p.71-72 and 74 of the present paper were collected from Xuma, Nanwang, Penglai City, Shandong Province, in 1977. No geological data on the sediments yielding the molars are available.

Mengyin (3 in Fig. 1) —

The mammoth molar (V.2610 discussed in p.76 of the present paper) was obtained from Andi Reservoir, Mengyin Country, Shandong Province. No information is available on its exact locality and fossil-bearing sediments, although Chow (1961) described it as "*Archidiskodon* cf. *planifrons*".

Tanchen (4 in Fig. 1) —

Chow (1961) reported a tusk fragment and a molar from the district of Tanchen, Shandong Province, and assigned them to "*Archidiskodon* sp." Of the two, the molar is discussed in p.81 of the present paper. Unfortunately, their exact locality and fossil-bearing bed are unknown, although Chow (1961) recorded that yellow fine sand and clay are attached to them, and You and Xu (1996) gave brief comments on the nature of the fossil-

* Locality number of Teilhard de Chardin and Trassaert (1937), where the place names are differently spelled.

bearing bed.

Qinxian (5 in Fig. 1) —

Hopwood (1935) originally described the mammoth molar from “S 5 li, Sung Chia Kou, S 4 li, Hung Ch’ü Kou, Ch’in Hsien (currently spelled Qinxian)”, Shanxi Province, and referred it to “*Archidiskodon* cf. *planifrons*”. The molar is redescribed herein (p.69), on the basis of the cast stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences (IVPP). Unfortunately, no information is available on its exact locality as well as the sediments yielding it, although Teilhard de Chardin and Young (1933) briefly described Late Cenozoic sediments exposed at several outcrops in the Chinsien (Qinxian) area.

Tunliu (6 in Fig. 1) —

The two unnumbered mammoth molars of Shanxi Institute of Cultural Relics (SICR) described in the present paper (p.73-76) were collected from Lingshang, Shangcun, Tunliu County, Shanxi Province. Zong *et al.* (1982) briefly described the stratigraphy and mammalian fossils of the Pleistocene sediments in Tunliu County. They divided the sediments excluding the overlying loess into three formations, namely the Xicun, Daqiang, and Xiaochangcun Formations in ascending order. According to them, the Xicun Formation yields mammalian fossils including *Stegodon* cf. *chiai* and *Proboscideipparion sinense*, but no elephantids. They assigned it to the early stage of the “Early Pleistocene”, on the basis of its faunal characteristics. Although the Daqiang Formation is barren, the Xiaochangcun Formation also yields mammalian fossils including “?*Archidiskodon* sp.”, and is assigned to the early stage of the Middle Pleistocene. The fossils referred to “?*Archidiskodon* sp.” by Zong *et al.* (1982) are different from the SICR specimens, because their localities are different from each other. Thus the chronological position of the SICR specimens is unknown.

Pinglu (7 in Fig. 1) —

The unnumbered mammoth molar of IVPP described in p.77 bears no records of its mode of occurrence, although it was illustrated by Chow and Chang (1974, Pl.XXV, Figs, 1, 2). The molar was collected in Pinglu County, Shanxi Province in 1954. The sediments yielding it are not known at all.

Linyi (8 in Fig. 1) —

The three mammoth cheek teeth of IVPP (V.2308, V.3044 and V.6753) were collected from Linyi County, Shanxi Province, which are discussed in p.81 and redescribed in p.77-78 of the present paper. Among the three, V.2308 and V.3044 were originally described by Chow and Chow (1959, 1965) as *Archidiskodon* cf. *planifrons* and *A.* sp. respectively. They also recorded that

a fossil mammal collection including the two molars was mostly collected from “the sands and gravels underlying the thick loessic beds at the village of Wuwang in Linyi”. The collection contains characteristic mammals including *Megantereon nihewanensis*, *Hipparion* sp., *Equus sanmeniensis*, *Euctenoceros boulei* and *Elaphurus bifurcatus*. On the basis of the faunal characteristics, they considered the fossils to be of “Early Pleistocene” or Villafranchian age. Many years later, Tang *et al.* (1983) studied vertebrate fossils newly obtained from the same area, and stratigraphy of the fossil-bearing beds. They recognized that the fossil-bearing beds were assigned to the Sanmen Formation, composed mainly of fluvio-lacustrine sands, overlain by the Lishi loess and underlain by the Pliocene mudstone. The mammoth cheek tooth (V.6753) was obtained from the Sanmen Formation, and originally identified as “*Palaeoloxodon tokunagai*”. The mammal fauna of the formation reported by them was basically identical to the fauna reported by Chow and Chow (1959, 1965), although they newly added several forms including *Stegodon* cf. *zdanskyi*, *Proboscideipparion sinense*, *Nestritherium* sp. and *Paracamelus* sp. On the basis of the faunal evidence, Tang *et al.* (1983) dated the formation as the “Early Pleistocene”, although non-faunal dating including paleomagnetism has not been made to the formation.

Dali (9 in Fig. 1) —

Wang (1988) reported the stratigraphy of the Plio-Pleistocene sediments at the fossil localities around Houhecun, Dali County, Shaanxi Province, and divided the sediments into late Pliocene lacustrine mudstone correlative of the Youhe Formation discussed in the next section, “Early Pleistocene” sands with abundant mammalian remains, and Middle Pleistocene sediments (gravel, sand, mud, loess and paleosol) in ascending order. These three units contact unconformably with each other. The mammalian fossil assemblage of the second unit, called the Houhecun Fauna, includes *Ochotonoides complicidens*, *Kowalskia dalinica*, *Mimomys* cf. *youhenicus*, *Myospalax omegodon*, *Equus* cf. *sanmeniensis* and *Elaphurus* cf. *bifurcatus*, as well as the primitive mammoth (originally assigned to “*Archidiskodon planifrons*”) discussed later in the present paper (p.76). Wang (1988) considered that the characteristics of the fauna indicated its age as the early “Early Pleistocene”, but other chronological evidences including paleomagnetic data have not been obtained so far from the sediments.

Weinan (10 in Fig. 1) —

Xue (1981) described fossil mammals from “green lacustrine deposits” exposed at the lower course of the Youhe River in the district of Weinan, Shaanxi Province,

which included *Ochotonoides* cf. *complicidens*, *Mimomys youhenicus* and *Plesiohipparion houfense*, as well as the primitive mammoth discussed later in the present paper (p.71; originally assigned to “*Elephas youheensis*”). The fossil-bearing lacustrine deposits and its fauna were called the “You-he Series” (=Youhe Formation) and You-he fauna (=Youhe Fauna) respectively, and were considered to be of early “Early Pleistocene” age by the faunal comparisons. Unfortunately, paleomagnetic measurements or other dating techniques have not been applied to the deposits.

Heshui (11 in Fig. 1) —

The mammoth molar described as *Archiskodon planifrons* by the Research Group for the Huanghe Elephant (1975) was obtained from a sand bed at the fossil locality numbered 73120 in Banchiao, Heshui, Gansu Province. The bed also yielded mammalian fossils including *Mimomys banchiaonicus*, *Proboscideipparion* sp., *Equus* sp. and *Gazella* sp. On the basis of the faunal characteristics, the research group assigned the age of the bed to the “Early Pleistocene”.

Pingliang (12 in Fig. 1) —

Zhang *et al.* (1983) proposed a new species of *Palaeoloxodon*, “*P. pingliangensis*”, on the basis of the M₃ (Pin. Mus. No. 1001) from Daqin, Pinglian Country, Gansu Province, which is discussed as *Mammuthus meridionalis* in p.76 of the present paper. They provided a stratigraphic section of the fossil locality, in which the M₃ was collected from a bed of sandy clay overlain by Late Pleistocene silty clay. The Pliocene *Hipparion* red clay was exposed about 5m below the bed. Such stratigraphic information does not indicate clearly the geological age of the fossil-bearing bed, although Zhang *et al.* (1983) considered it as the Middle Pleistocene. Furthermore, no information on its mammalian fauna in association with the M₃ was given by Zhang *et al.* (1983).

3.3 Chronological Conclusion of the Fossil Localities

The fossil localities described above can be divided into the following three groups on the basis of the chronological data available for each locality:

Group I (Paleomagnetically dated localities with relatively reliable ages): The localities in the Nihewan and Yushe Basins, and Xihoudu are allocated. The chronological relationship among these localities is shown in Fig. 4. Of the localities, Goudi, Xiaochangliang, Donggutuo and Xihoudu have definite metric ages. The remaining localities show relatively rough chronological ranges.

Group II (Localities roughly dated by faunal evidence): Tianzhen, Linyi, Dali, Weinan and Heshui are allocated. All the localities were assigned to the “Early Pleistocene”

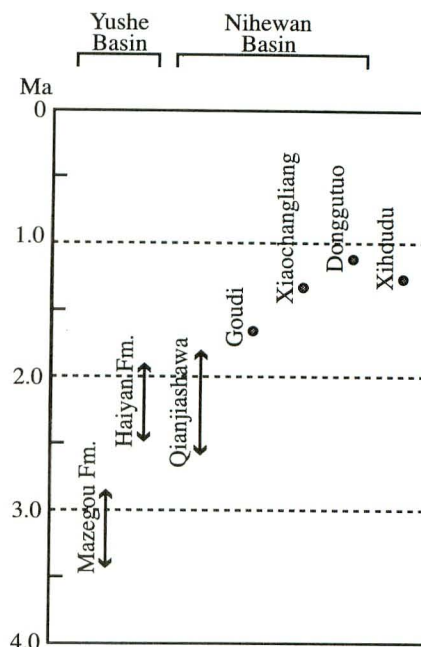


Fig. 4 Chronological relationship among the mammoth localities dated paleomagnetically.

by the original authors.

Group III (Localities with no or unreliable chronological data): Penglai, Mengyin, Tanchen, Qinxian, Tunliu, Pinglu and Pinliang are allocated.

The localities allocated to Group I can be used exclusively for the detailed biostratigraphic discussion in Chapter 5.

4. Systematic paleontology

4.1 Terminology and measuring method

The terminology and measuring method for cheek teeth adopted here are shown in Fig. 5, which mainly follow those of Maglio (1973), Nojiriko Excavation Research Group (1975) and Wei *et al.* (2003). The crowns of elephantid cheek teeth are composed of many distinct plates (or lamellae) and transverse valleys with U-shaped sections between them. Half plates (or talons) are usually attached on the mesial and distal ends of the crowns. They show incomplete plate features, and are smaller than all of complete plates. Semi-plates sometimes appear on the labial or lingual side of the middle part of the crown. All the complete and incomplete plates are covered with cementum. On the abrasion surface, enamel figures of each plate are represented by a row of enamel rings in the earliest stage of abrasion. With the advance of abrasion, these enamel rings are connected to each other to form somewhat complicated enamel loops. The enamel rings and loops are divided from each other by shallow grooves

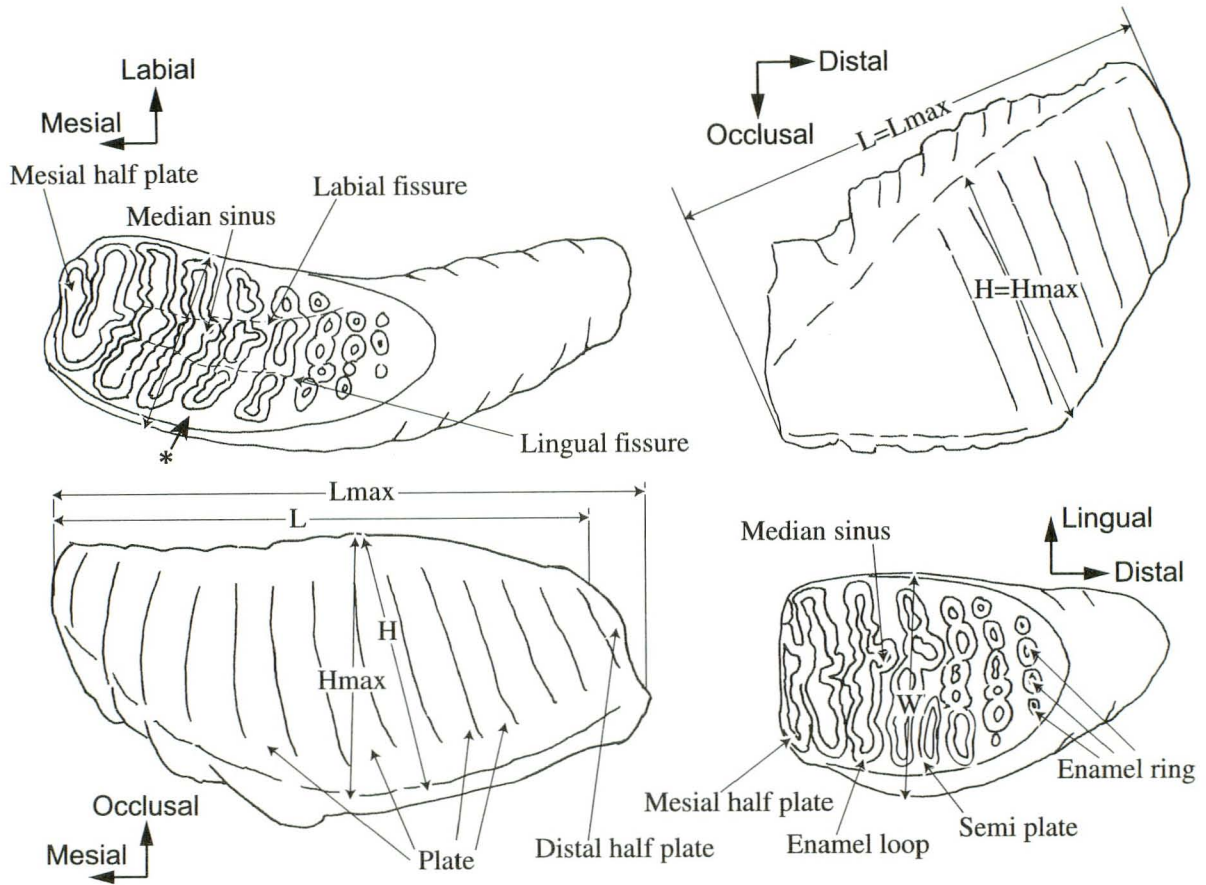


Fig. 5 Diagram of elephantid molars in occlusal and lateral views, showing the terminology and measurements taken. Left figure: right M_3 , Right figure: right M^3 . For the abbreviations and symbol (*) see text.

running mesio-distally. Among these grooves, strong ones develop in the labial and lingual parts of the crown, and somewhat strong one develops in the central part. They are called lateral (labial and lingual) and median fissures respectively. The enamel loops at the central part sometimes have median sinuses projecting distally and/or mesially.

P (Plate number) —

The number of the plates is expressed as follows: The number of the complete plates is added by "x", "1/2", "∞" and "+". Among them, "x" and "1/2" mean the half-plates and semi-plates respectively. "∞" indicates that the mesial part of the crown has been worn out, and "+" means that the mesial and/or distal parts have been lost by some other reasons than normal abrasion. In this paper, the preserved plates except half and semi plates are numbered as the first plate, the second plate and so on from the most mesial plate to the most distal plate.

L (Length of crown) —

In upper cheek teeth, the measurement should be taken vertically to the average plate plane. In lower cheek

teeth, it is measured from the mesial end of the occlusal surface of the mesial half plate (or mesial end of the abrasion surface) to the distal end of the occlusal surface of the distal half plate. It should be taken parallel to the abrasion surface of the crown of lower cheek teeth.

Lmax (Maximum length of crown) —

In upper cheek teeth, it is always equal to *L* of the same specimen. In lower cheek teeth, however, it is the mesio-distal maximum length of the crown. It is measured parallel to the abrasion surface of each tooth.

W (Maximum width of crown) —

This value is the labio-lingual maximum width of the widest plate, including cementum. It is measured parallel to the transverse axis of the plates. In incomplete specimens, the widest plate preserved may not be originally the widest one.

H (Height of crown) —

This value is the occluso-cervical maximum height of the unworn highest plate, measured along the plate.

Hmax (Maximum height of crown) —

In upper cheek teeth, this value is equal to *H* of the

same specimen. In lower cheek teeth, it is measured vertically to the abrasion surface.

E (Average enamel thickness) —

The measurement should be made at right angles to the enamel/dentine boundary and enamel/cementum boundary. Otherwise, oblique abrasion of the crown causes the enamel surface being thicker mesio-distally than its actual thickness. The actual thickness of enamel varies from one part of the plate to another, being generally thicker towards the apex and around the sides of the plate and on median sinuses. Thus, it is better to average a series of measurements.

LF (Lamellar frequency) —

LF is the average number of plates in a distance of 10cm along the mesio-distal axis of the cheek teeth. The most accurate measurement is to calculate LF from the number of the complete plates (excluding the terminal half plates) and the length of the series of the plates. Each LF is taken at right angles to the plate at four points (base and preserved top of crown, labial and lingual sides) and averaged.

Hypsodonty index (HI) —

It is calculated by multiplying the H (Height)/W (Width) ratio by 100.

4.2 Systematic description

Family **Elephantidae** Gray, 1821

Genus ***Mammuthus*** Brookes, 1828

Remarks

In paleontological studies of the elephantids, cheek teeth have been generally examined morphologically instead of skulls, because well preserved skulls have been rarely found. But the morphology of the cheek teeth considerably changes with the advance of abrasion, and it is impossible to observe simultaneously the whole tooth row of an individual, because the elephantid teeth are replaced successively and horizontally. Thus it is not easy to distinguish the genera and species of the elephantids, which resulted in the confusion of their classification among Chinese paleontologists, as mentioned before.

In the present paper, we present diagnostic characters to discriminate cheek teeth of four representative elephantid genera on the basis of previous authors (e.g. Matsumoto, 1924; Osborn, 1942; Maglio, 1973; Lister and van Essen, 2003) with the addition of our own observation, as follows:

Mammuthus

1) The median sinus is blunt in shape. It is well developed in early species, but sometimes absent

in advanced species.

- 2) The folding of the enamel layer is generally weak, but is partially marked in early species.
- 3) When the enamel figure is composed of one transverse enamel loop, the enamel layers of the mesial and distal sides are parallel with each other.
- 4) In the most anterior plate with a tripartite enamel figure (asterisked in Fig. 5), the labio-lingual length of the central enamel loop is equal to or shorter than those of the two lateral enamel loops.

Palaeoloxodon

- 1) The median sinus is small, but pointed (small "loxodont sinus").
- 2) The enamel layer folds strongly and irregularly in the central part of the enamel loop.
- 3) When the enamel figure is composed of one transverse enamel loop, its central part is rather wider mesio-distally than the lateral parts, and it shows an elongated rhombic shape.
- 4) In the most anterior plate with a tripartite enamel figure (asterisked in Fig. 5), the central enamel loop is longer labio-lingually than the two lateral enamel loops.

Elephas

- 1) The median sinus is not developed in the advanced species.
- 2) The enamel layer folds strongly and regularly in almost all the parts of the enamel loop.
- 3) When the enamel figure is composed of one transverse enamel loop, the enamel layers of the mesial and distal sides are parallel with each other.

Loxodonta

- 1) The median sinus is rather large and pointed (typical "loxodont sinus").
- 2) The enamel layer folds very weakly.
- 3) When the enamel figure is composed of one transverse enamel loop, its central part is clearly wider mesio-distally than the lateral parts, and it shows a rhombic shape.

In Europe, many authors have presented the measurements of the mammoth cheek teeth in their studies on the evolution of the mammoths (Table 1). Among them, Lister and Sher (2001) and Lister *et al.* (2005) treated the number of the complete plates in the third molars as the key character by which each species was distinguished, and the evolutionary level of the Eurasian mammoth lineage was indicated. We also use this character to classify mammoth remains from northern China into species. Other indicators, such as E (enamel thickness), HI (hypsodonty index) and LF (lamellar frequency) are less valuable, because they are influenced

Table 1 Comparative measurements for the third molars of the five species of *Mammuthus* from Africa, Eurasia and North America (Modified from Wei *et al.*, 2003). P: number of complete plates, N: number of specimens. For other abbreviations see text and Fig. 5. Lmax, W, H, and E are in millimeters.

Species and Data Source	Area	Portion	P	Lmax	W	H	E	LF	HI
<i>M. subplanifrons</i>									
Data by Maglio (1973)	Africa	M ³	7-8 (N=4)	202.8-229.2	81.0-122.0	49.0-85.0	3.4-5.0 (N=5)	2.6-4.1 (N=7)	56.3-91.0 (N=6)
Ditto	Ditto	M ₃	8-9 (N=2)	259.0-325.1	63.7-111.5	45.0-80.9	3.5-5.5 (N=9)	3.1-4.3 (N=10)	59.0-89.0 (N=9)
<i>M. rumanus</i>									
Holotype (Ștefănescu, 1924)	Romania	M ₃	4+ (probably 9, possibly 10)	160+	-	-	-	3.0 (Estimated about 4.0)	-
Neotype (Lister and van Essen, 2003)	Romania	M ³	8 or 9	-	-	-	4.25	3.07	-
Data by Lister and van Essen (2003)	Europe	M ³	8 or 9-10 (N=3)	-	-	-	3.0-4.25 (N=4)	3.07-4.94 (N=4)	118-135 (N=2)
Ditto	Ditto	M ₃	10 (N=2)	-	-	-	3.0-5.0 (N=2)	3.0-4.93 (N=3)	120 (N=1)
<i>M. meridionalis</i>									
Lectotype (Maglio, 1973)	Upper Valdarno, Italy	M ³	12	283.8	120.6	-	3.3 (2.8-3.7)	4.4	-
Ditto	Ditto	M ₃	13	311.7	126.4	-	3.6 (3.2-3.9)	4.2	-
Data by Maglio (1973)	Eurasia	M ³	11-14	228.8-317.1	85.6-126.4	100.2-141.8	2.6-4.1	3.7-6.1	93.8-152.7
Ditto	Ditto	M ₃	10-14	212.0-306.0	69.1-119.4	75.0-152.0	2.4-4.1	3.5-5.9	107.8-165.5
Data by Dubrovo (1977)	Upper Valdarno, Italy	M ³	11-13	240-298	85-122	-	-	4.5-5	-
Ditto	Ditto	M ₃	11-14	220-320	-	-	-	4-5	-
Data by van Essen (2003)	Upper Valdarno, Italy	M ³	12-14	220.0-335.0	80.0-123.5	104.0-147.0	2.5-3.8	4.18-6.41	113.0-147.0
Ditto	Ditto	M ₃	12-15	250.0-330.0	75.0-110.0	101.0-135.0	2.2-4.2	3.83-6.55	120.0-130.0
<i>M. trogontherii</i>									
Type (Pohlig, 1885)	Süssenborn, Germany	M ³	15+	-	-	-	-	-	-
Ditto	Ditto	M ₃	16+	-	-	-	-	-	-
Data by Maglio (1973)	Eurasia	M ³	14-21	213.0-358.0	57.0-107.5	118.0-218.0	1.5-3.0	6.0-8.2	145.3-304.9
Ditto	Ditto	M ₃	15-21	236.0-340.0	70.0-113.0	96.0-160.0	1.8-3.0	5.0-7.2	133.2-206.6
Data by Dubrovo (1977)	Süssenborn, Germany	M ³	18-23	246-400	73-120	129-212	2-3	4-7	143-208
Ditto	Ditto	M ₃	16-21	225-383	74-114	127-167	2-3	4-7.5	140-179
<i>M. primigenius</i>									
Data by Maglio (1973)	Eurasia & N. America	M ³	20-27	226.0-285.0	68.0-113.0	135.0-188.5	1.3-2.0	6.5-11.1	164.6-211.8
Ditto	Ditto	M ₃	20-25	207.0-320.2	65.0-100.0	123.0-184.1	1.3-2.0	6.8-10.2	137.8-189.2

by the molar size, abrasion level, measuring method and so on. The key to the species is given below.

Key to the primitive species of the genus *Mammuthus*

1. The number of complete plates ranges from eight or nine to ten in M^3 , and is ten in M_3 ---- *M. rumanus*
2. The number of complete plates is usually 12 to 14 and rarely 11 or 15 not only in M^3 but also in M_3 ----- *M. meridionalis*
3. The number of complete plates ranges from 17 to 22 in M^3 and M_3 ----- *M. trogontherii*

Mammuthus rumanus (Ștefănescu, 1924)

Selected synonyms

Elephas antiquus rumanus; Ștefănescu 1924, *C. R. Acad. Sci. Paris*, **179**, 1418. Original figure (as *E. cf. meridionalis*) in Athanasiu, 1912 (1915), pl.17, fig.4.

Archidiskodon cf. planifrons (Falconer and Cautley); Hopwood 1935, *Palaeont. Sinica*, Ser. C, **9**, (3), 88-90, pl. 8, fig. 1.

Archidiskodon planifrons (Falconer and Cautley); Teilhard de Chardin and Trassaert, 1937 (in part), *Palaeont. Sinica*, Ser. C, **8**, (1), 43-44, pl. 12, fig. 3.

Elephas planifrons Falconer and Cautley; Maglio 1973 (in part), *Trans. Amer. Phil. Soc.*, **63**, 42-46, pl. 12, fig. 4.

Elephas youheensis; Xue 1981, *Vertebrata Palasiatica*, **19**, 35-37, pl. 1, figs. 1a, 1b.

Mammuthus rumanus (Ștefănescu); Lister and van Essen 2003, *Advances in Vertebrate Paleontology 'Hen to Panta'*, 47-52, figs. 1, 2.

Diagnosis

M^3 with eight or nine to ten plates, while M_3 with ten plates; plates thick and lamella frequency low (3-5); enamel layer thick; hypsodonty index low.

Description

M^3 (Unnumbered) —

Material and storage: Unnumbered cast stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing (Plate 1, figs. 1-2).

Locality: S 5 li, Sung Chia Kou, S 4 li, Hung Ch'ü Kou, Ch'in Hsien (Qinxian), Shansi (Shanxi).

See the original description by Hopwood (1935). This specimen is the cast of the distal part of a moderately worn left M^3 with nine plates and a distal half plate. The plates are rather thick and widely spaced. In occlusal view, the crown is slightly concave toward the lingual side. The abrasion surface is apparently convex in lateral view. The plates are weakly convergent toward the lingual side in occlusal view, whereas nearly parallel to one another in lateral view. Both of the width and height of the distal plates are obviously reduced toward the distal end of the

crown. The enamel layers are generally smooth, and weakly folded on some wear figures.

The first plate is badly broken and only an indistinct enamel fragment is preserved on the labial side. Most of the mesio-lingual part of the second plate is also broken off. The wear figure of the third plate shows a single large transverse enamel loop. The mesial and distal sides of the loop are approximately parallel to each other in occlusal view, with a prominent and acute distal median sinus. The lateral fissure of the lingual side is represented by the constriction of the enamel loop. The wear figures of the fourth, fifth and sixth plates are divided into three parts by the lateral fissures. That of the fourth plate shows the typical tripartite structure of three closely connected and subequal-sized enamel loops. Among them, the lingual one is rectangular with round corners, whereas the central and labial ones are somewhat oval in shape. A prominent and obtuse distal median sinus is visible in the median part of the central enamel loop.

The wear figure of the fifth plate also shows the tripartite structure of three separated enamel loops with different sizes. Among them, the central one is the largest and the labial one is the smallest. The two lateral enamel loops are nearly rectangular with round corners, whereas the central enamel loop is rather irregular, with the strong mesio-distal constriction by the median fissure. The wear figure of the sixth plate is subdivided into two subequal lateral enamel loops and central part consisting of three subequal-sized enamel rings. The seventh plate is in a beginning stage of wear. The eighth and ninth plates and the distal half plate are still unworn, which are covered with thick cement.

M_3 (THP18.906) —

Material and storage: THP18.906 stored in Tianjin Natural History Museum, Tianjin (Plate 1, figs. 3-4).

Locality: Loc. 20, Liyucun, Yushe, Shanxi.

Horizon: The upper part of the Mazegou Formation.

See the original description by Teilhard de Chardin and Trassaert (1937). This specimen is the distal part of a broken right M_3 with five plates and a distal half plate. The enamel layers are remarkably thick, generally smooth and slightly folded. In occlusal view, the crown is slightly convex toward the lingual side. The abrasion surface is slightly concave in lateral view. The width of the plates is gradually reduced toward the distal end of the crown. The plates are convergent to the labial side of the crown in occlusal view and to the occlusal side of the crown in lateral view. The distal half plate is obviously lower than the preceding plates in lateral view. The cervical line is somewhat convex radically in lateral view.

Table 2 Measurements for the molars of the primitive mammoths from northern China. For the abbreviations see text and Fig. 5.

Portion	Number	Locality	Horizon	p	Lmax (mm)	W (mm)	H (mm)	E (mm)	LF	HI	Original attribution	Data source
<i>Mammuthus rumanus</i>												
l. M ¹	Unnumbered	Qinxian, Shanxi		+9x	236+	106	112+		3.8	106+	<i>A. cf. planifrons</i>	
r. M ₃	THP18.906	Loc. 20, Liyucun, Yushe, Shanxi	Upper part of the Mazegou Fm.	+5x	182+	107	75+	5.5	3.6	70+	<i>A. planifrons</i>	
r. M ₃	75Wei②1.1-1.2	Weinan, Shaanxi	Youhe Fm.	78-9x	2240-250	100+	80+	4.2-5.6	3.2	80+	<i>E. youheensis</i>	Xue, 1981
<i>Mammuthus meridionalis</i>												
r. M ²	77004	Nanwangxiang, Penglai, Shandong		x9x	227	102	135	4.6	4.1	132		
l. M ²	THP10.464	Loc.6, Haiyan, Yushe, Shanxi	Haiyan Fm.	∞7x	152	101	37+	3.7	5.0	37+	<i>A. tokunagai</i>	
M ²	78DL02	Houhecutun, Dali, Shaanxi		x8x	190	77	-	3-4	4.73	-	<i>A. planifrons</i>	Wang, 1988
r. M ²	THP10.459	Loc.6, Haiyan, Yushe, Shanxi	Haiyan Fm.	x13x	268	114	158±	3.9	4.8	139		
l. M ²	THP10.461	Loc.6, Haiyan, Yushe, Shanxi	Haiyan Fm.	x13x	268	118	150±	3.8	4.7	127	<i>A. tokunagai</i>	
r. M ²	Unnumbered	Shangcun, Tunliu, Shanxi		+11x	222	115	140±	3.4	5.0	122+		
M ³	78DL01	Houhecutun, Dali, Shaanxi		x11x	310	99.6	-	3.5-5	3.37	-	<i>A. planifrons</i>	Wang, 1988
r. M ²	V4760	Loc.73120, Banqiao, Heshui, Gansu		x11	316	110	134	-	3.75	122	<i>A. planifrons</i>	Research Group for the Huanghe Elephant, 1975
l. M ₂	77005	Nanwangxiang, Penglai, Shandong		+6x	169+	97	100+	4.6	4.0	103+		
M ₂	78DL02	Houhecutun, Dali, Shaanxi		x9x	203	71	-	3-4	4.97	-	<i>A. planifrons</i>	Wang, 1988
l. M ₄	THP10.460	Loc.6, Haiyan, Yushe, Shanxi	Haiyan Fm.	x14x	350	101	140	3.9	4.2	139	<i>A. tokunagai</i>	
r. M ₄	THP10.462	Loc.6, Haiyan, Yushe, Shanxi	Haiyan Fm.	x14x	360	102	143	3.7	4.5	140	<i>A. tokunagai</i>	
l. M ₄	Unnumbered	Shangcun, Tunliu, Shanxi		+15+	318+	122	148+	3.5	5.1	121+		
M ₄	78DL01	Houhecutun, Dali, Shaanxi		x11x	270	86.4	-	3.5-5	4.44	-	<i>A. planifrons</i>	Wang, 1988
r. M ₂	No.1001	Daqin, Pingliang, Gansu		+13x	365+	102	117	4.5-5.5	4.5	114	<i>P. pingliangensis</i>	Zhang <i>et al.</i> , 1983
l. M ₃	V2610	Mengyin, Shandong		+9+	197+	103	168+	3.8	4	163+	<i>A. cf. planifrons</i>	
l. M ₂ or M ₃	Unnumbered	Qianjiashawa, Yangyuan, Hebei	Lower part of the Nihewan Fm.	+7+	130+	94+	69+	3.4	4.8	73+		
<i>Mammuthus trogontherii</i>												
l. M ²	Unnumbered	Majuangou, Yangyuan, Hebei	Middle part of the Nihewan Fm.	∞9x	124+	79	50+	2.8	8.0	63+	<i>M. trogontherii</i>	Wei <i>et al.</i> , 2003
r. M ²	Unnumbered	Donggutuo, Yangyuan, Hebei	Uppermost part of the Nihewan Fm.	∞4x	74.3	82	-	1.5-2.3	7-8	-	<i>P. sp.</i>	Wei <i>et al.</i> , 1985
l. M ²	V2849	Xihoudu, Ruicheng, Shanxi	Xihoudu Fm.	∞5x	114	82	48+	3.4	5.0	59+	<i>A. planifrons</i>	
r. M ²	Unnumbered	Pinglu, Shanxi		x17x	313	91	160	-	5.8	176	<i>M. trogontherii</i>	
l. M ²	V13610	Majuangou, Yangyuan, Hebei	Middle part of the Nihewan Fm.	x17 ^{1/2} x	264	89	163	2.0	7.3	183	<i>M. trogontherii</i>	Wei <i>et al.</i> , 2003
l. upper M	V12031	Xiaochangliang, Yangyuan, Hebei	Upper part of the Nihewan Fm.	x4+	-	-	-	2.5-3.0	-	-	<i>P. sp.</i>	Tan <i>et al.</i> , 1995
r. Dp ₄	V6753	Liangjiapo, Linyi, Shanxi	Sanmen Fm.	x10	126	55	57	2.2	8.0	104	<i>P. tokunagai</i>	
l. Dp ₄	V2844	Xihoudu, Ruicheng, Shanxi	Xihoudu Fm.	x7+	-	46	51	-	-	111	<i>P. cf. namadicus</i>	Chia & Wang, 1978
l. M ₁	V2843	Xihoudu, Ruicheng, Shanxi	Xihoudu Fm.	x10x	164	71	90	2.5-3.5	7.0	127	<i>P. cf. namadicus</i>	Chia & Wang, 1978
l. M ₃	TI-C83-10-12	Donggutuo, Yangyuan, Hebei	Uppermost part of the Nihewan Fm.	x16+	335+	93	160	3.0	5.3	172		
l. M ₃	V2849	Xihoudu, Ruicheng, Shanxi	Xihoudu Fm.	x11+	185+	89	142+	3.5	5.0	160+	<i>A. planifrons</i>	
r. M ₃	Unnumbered	Majuangou, Yangyuan, Hebei	Middle part of the Nihewan Fm.	x17x	306	87	120+	2.8	6.4	138+	<i>M. trogontherii</i>	Wei <i>et al.</i> , 2003
<i>M. rumanus</i> and/or <i>M. meridionalis</i>												
l. M ₁	THP33.132	Yushe, Shanxi		+3x	94+	81	82+	4.0	4.6	101+		
l. M ₂	THP10.456	Yushe, Shanxi		+7x	179+	85	96+	4.7	4.2	113+	<i>A. tokunagai</i>	
l. M ₂	THP18.898	Yushe, Shanxi		+6 ^{1/2} x	175+	89	94+	4.5	4.0	106+	<i>A. tokunagai</i>	
l. M ₂	THP30.803	Yushe, Shanxi		x6+	173+	85	110	4.8	4.5	129		
<i>M. sp. indet.</i>												
r. Dp ³	Unnumbered	Loc.81018, Gaoya, Tianzhen, Shanxi		+3x	-	45	-	1.8	-	-		
r. Dp ⁴	Unnumbered	Loc.81018, Gaoya, Tianzhen, Shanxi		x3+	-	53	59	2.2	-	111±		
r. M ¹	V2308	Panhou, Linyi, Shanxi	Sanmen Fm.	+8x	169+	105	69+	4.3	4.5	66+	<i>A. cf. planifrons</i>	
M ₁	V3044	Panhou, Linyi, Shanxi	Sanmen Fm.	-	-	-	-	-	-	-	<i>A. sp.</i>	Chow & Chow, 1965
l. M ₂	Unnumbered	Tanchen, Shandong		+7x	200+	100±	-	3	4	-	<i>A. sp.</i>	Chow, 1961

The wear figures of this molar are generally similar to those of the Qinxian specimen. The wear figures of the first and second plates show the tripartite structure with two elongated lateral enamel loops and a somewhat irregular central loop. Among them, the central one is shorter labio-lingually than the two lateral ones in the first plate, whereas in the second plate, it is longer than the labial one but shorter than the lingual one. Between the central and lateral loops, a very strong labial lateral fissure and moderately strong lingual lateral fissure are observed in these plates. Furthermore, a prominent median sinus of the mesial side and a weak median fissure are visible in the central enamel loop. The enamel figures of the third, fourth and fifth plates are also subdivided into two lateral and a central parts by two lateral fissures. The central part consists of several enamel rings or enamel loops or slightly worn mammillae. The lateral parts of the plates are represented by enamel rings or oval shaped enamel loops.

Discussion

The two molars described above evidently belong to the genus *Mammuthus*, because their enamel figures agree with those of the genus already mentioned in p.67. The molars are estimated to have nine or ten complete plates from the morphology of the preserved parts, and thus they are referable to *M. rumanus*. The other measurements such as E and LF of them also agree with those of the molars of *M. rumanus* shown by Lister and van Essen (2003).

Aside from the two molars from Shanxi, the lower third molar from Weinan (75Wei①1.1-1.2) named *E. youheensis* by Xue (1981), is comparable to European *M. rumanus* in its morphology and metrical data. For example, its P, E and LF approximately fall within the range of the European *M. rumanus* (Tables 1 and 2). Consequently this molar is assigned to *M. rumanus* here.

In this paper, we can examine only the three specimens of *M. rumanus*, and it can be said that the remains of this species is few in northern China as in Europe.

Mammuthus meridionalis (Nesti, 1825)

Selected synonyms

- Elephas meridionalis*; Nesti 1825, *Nuov. Giorn. Lett.*, **11**, (24), 211, pl. 1, figs. 1, 2.
Elephas antiquus; Falconer and Cautley 1845-1849 (in part), *Fauna Antiqua Sivalensis*, pl. 14B, figs. 17, 18; pl. 42, fig. 19; pl. 44, figs. 19.
Elephas lyrodon; Weithofer 1889, *Jahrb. Geol. Reichsanst.*, **39**, (1), 79; 1890, *Beitr. Pal. Osterr.-Ungarns*, **8**, 172, pl. 3, fig. 2; pl. 4, fig. 2; pl. 5, fig. 1; pl. 6, figs. 1-2.
Elephas planifrons Falconer et Cautley; Depéret and Mayet 1923,

Ann.Univ. Lyon, n.s. I, **42**, (II), 101-120, pl. 4, figs.1-6, 8; pl. 5, figs. 1-5; text figs. 4-15.

Archidiskodon tokunagai Matsumoto; Teilhard de Chardin and Trassaert, 1937 (in part), *Palaeont. Sinica*, Ser. C, **8**, (1), 44-46, pl.9, figs.1a, 1b, 2; pl.10, figs.1a, 1b, 2.

Archidiskodon meridionalis Nesti; Osborn 1942, *Proboscidea*, Vol. II, 969-980, figs. 858-864; fig. 865 (7-9, 11-15); figs. 866-868.

Archidiskodon cf. planifrons (Falconer et Cautley); Chow 1961, *Vertebrata Palasiatica*, **1961**, 361-362, pl. 1, figs. 1, 1a.

Archidiskodon gromovi; Alexeeva and Garutt 1965, *Bjull. Komiss. po Izucheniju Chetverrichnogo Perioda*, 161-166, figs.1, 3. (not seen)

Mammuthus meridionalis (Nesti); Maglio 1973 (in part), *Trans. Amer. Phil. Soc.*, **63**, 53, 55-57, pl. 17, figs. 1-5.

Archidiskodon planifrons Falconer et Cautley; Research Group for the Huanghe Elephant 1975, *The Huanghe Elephant*, 41-42, pl. 12, fig. 2.

Palaeoloxodon pingliangensis; Zhang et al. 1983, *Vertebrata Palasiatica*, **21**, 65-67, pl. 1.

Archidiskodon planifrons Falconer et Cautley; Wang 1988, *Vertebrata Palasiatica*, **26**, 64-66, pl. 1, figs. 15, 15a.

Diagnosis

M³ and M₃ with 11 to 15 plates; plates moderately thick and lamella frequency moderate (3.5-6.5); enamel layer moderately thick; hypsodonty index moderate.

Description

M² (SD77004) —

Material and storage: SD77004 stored in Shandong Provincial Museum, Jinan, Shandong (Plate 2, figs. 1-2).

Locality: Xuma, Nanwang, Penglai, Shandong.

This specimen is a moderately worn right M². Nine plates, and a mesial and distal half plates are well preserved. This molar is remarkably large, and broad and high. The enamel layers are rather thick, generally smooth, and only roughly folded on some wear figures. The plates are thick, widely spaced, and covered with thick cement. The crown is slightly concave lingually in occlusal view. The abrasion surface is slightly convex in lateral view. The widths of the plates are nearly the same, and only weakly decrease toward the distal end of the crown. The greatest width is measured at the fifth plate. The plates are slightly convergent lingually in occlusal view. The distal margin of the crown is considerably convex in lateral view.

The lingual half of the mesial half plate is merged with the first plate, whereas its labial half is still detached. A remarkably large blunt median sinus is observed on the distal enamel layer of the first plate. The wear figure of the second plate shows only a large transverse enamel loop, with the mesial and distal sides approximately parallel. Its distal median sinus is relatively acute and smaller than that of the first plate. The wear figure of the third plate is

subdivided into two incompletely merged enamel loops. The lingual enamel loop is much smaller than the labial enamel loop with an irregular shape. Its mesial and distal sides are parallel. In the labial enamel loop, the lingual part is strongly swollen and folded, and the labial part strongly curves distally. The wear figure of the fourth plate is subdivided into two lateral enamel loops and a central enamel loop by lateral fissures. The two subequal lateral loops are slightly shorter labio-lingually than the central one. In the median part of the central loop, a mesial and distal median sinuses are observed as weak expansions. On the labial side of the median sinuses, the central loop is constricted by the median fissure. The wear figure of the fifth plate is divided into two lateral enamel loops and a central part by lateral fissures. Moreover, the median fissure subdivides the central part into two parts which consists of two subequal enamel rings. The wear figure of the sixth plate is subdivided into six subequal enamel rings. The seventh plate is in a beginning stage of abrasion, and its lateral mammillae are not worn.

M² (THP10.464) —

Material and storage: THP10.464 stored in Tianjin Natural History Museum, Tianjin (Plate 2, fig. 3).

Locality: Loc. 6, Haiyan, Yushe, Shanxi.

Horizon: Haiyan Formation.

The original description was given by Teilhard de Chardin and Trassaert (1937). This specimen is a very strongly worn left M² with seven plates and a distal half plate. It belongs to the same individual as the M³ (THP10.461) described later, and is assignable to the preceding tooth of the M³. The mesial end of the crown is strongly worn, so that the enamel of some mesial plates is lost. The mesio-lingual corner of the crown is broken. The distal margin of the crown is abraded by the contact with the following molar (THP10.461), and thus most of the distal half plate and a part of the seventh plate are worn out. The crown is slightly concave lingually in occlusal view. The labio-lingual widths are nearly equal in all the preserved plates. The plates are nearly parallel to each other in occlusal view. They are rather thick, closely spaced, and covered with thick cement. The enamel layers are generally smooth, and only weakly folded in some wear figures of the plates.

The wear figures of the first to third plates are connected with each other in their median or labial parts. In the labial parts of the second and third plates, a “reversed” enamel loop is formed with the connection of a part of the distal enamel layer of the second plate and that of the mesial enamel layer of the third plate. The labial part slightly shifts more mesially than the lingual part in the wear

figures of the third and fourth plates. The wear figures of the fourth to sixth plates form transverse enamel loops which show elongated rectangular shapes with round corners. They are convex mesially. Among them, the enamel loop of the sixth plate connects with that of the seventh plate in the medial part. The seventh plate and the distal half plate are severely abraded not only by mastication, but also by the contact with the following molar, so that the enamel layers of these plate and half plate are lost except their lingual parts.

The median sinuses are observed on the mesial sides and/or the distal sides of the wear figures of the third to seventh plates. The continuation of the enamel layers between the second and third plates and between the sixth and seventh plates also indicates the development of the median sinuses in these plates.

M³ (THP10.459) —

Material and storage: THP10.459 stored in Tianjin Natural History Museum, Tianjin (Plate 3, figs. 1-2).

Locality: Loc. 6, Haiyan, Yushe, Shanxi.

Horizon: Haiyan Formation.

See the original description by Teilhard de Chardin and Trassaert (1937). This molar is a well preserved right M³ with 13 plates and with a mesial and distal half plates, in an early stage of wear. The crown is remarkably broad, whereas it is relatively short, and is covered with thick cement. The lingual side of the crown is slightly convex, but its labial side is strongly convex in occlusal view. Thus the crown is convex labially. The abrasion surface is weakly convex in lateral view. The plates are rather thick mesio-distally. They are straight occluso-cervically and nearly parallel to one another in lateral view. The width and height of distal plates strongly reduce toward the distal end of the crown. The greatest width is measured at the third plate. The enamel layers are thick and generally smooth. The mesial half plate is mesio-distally much thinner than the succeeding plates and its mesial side is lost by the contact with the preceding right M². The wear figure of the mesial half plate is subdivided into a rather large and irregularly folded enamel loop, and two much smaller lingual enamel rings.

The wear figure of the first plate shows a rather irregular and large transverse enamel loop, with its labial part slightly stepping forward. The labial part is somewhat thicker mesio-distally than the lingual part. The median part of the distal side is strongly emarginated mesially. The second plate is somewhat oblique to the first plate in occlusal view. Its wear figure also shows a rather irregular and large transverse enamel loop. Its labial end somewhat curves distally. The distal median sinus is remarkably

large and nearly semicircular in shape, whereas the mesial median sinus is much smaller but acute. The wear figure of the third plate is subdivided into a central part and two lateral enamel loops by lateral fissures. Among them, the labial and lingual enamel loops show a long rectangular shape with round corners, and the former is obviously longer labio-lingually than the latter. The central part is as long as the labial part, and moreover subdivided into a labial oval enamel loop and a lingual dumbbell shaped enamel loop by a median fissure. The long axis of the latter elongates mesio-lingually. The distal half of the latter represents a large blunt median sinus. In the fourth and fifth plates, the wear figure is also divided into a labial, lingual and central parts. Among these parts, the central one is subdivided into two parts by a median fissure as in the third plate. But the labial half of the central part of the fourth and fifth plates consists of two enamel rings or loops. The sixth plate is in an early stage of wear, so that two oval enamel rings and two slightly worn mammillae are observed. The seventh to 13th plates and the distal half plate are still unworn, and are covered with thick cement.

*M*³ (THP10.461) —

Material and storage: THP10.461 stored in Tianjin Natural History Museum, Tianjin (Plate 3, figs. 3-4).

Locality: Loc. 6, Haiyan, Yushe, Shanxi.

Horizon: Haiyan Formation.

See the original description by Teilhard de Chardin and Trassaert (1937). This molar is a left *M*³, which is assignable to the pair specimen of THP10.459 described above. Except for the abnormal subdivision and arrangement of the plates and their wear figures, it strongly resembles its pair in general characters.

The wear figure of the mesial half plate resembles that of the pair specimen. The wear figure of the first plate shows only an irregular and large transverse enamel loop, with the labial part slightly stepping more mesially than the lingual part. The labial part is somewhat broader mesio-distally than the lingual part. The lingual and median parts of the distal side are somewhat irregularly and roughly folded. In occlusal view, each of the second to seventh plates is subdivided into two parts by a median fissure, and the labial part is clearly placed more mesially than the lingual part. Moreover, the labial part is longer labio-lingually than the corresponding lingual part. In the second plate, each of the wear figures of the lingual and labial parts shows only a single enamel loop. In the lingual enamel loop, the labial end is obviously swollen distally forming a distal median sinus. In the third plate, the wear figure of the labial half shows only an irregular enamel loop. The lingual part of this enamel loop obviously

broadens mesio-distally, with its lingual end somewhat pointed. The wear figure of the lingual half of the third plate also shows a single enamel loop, which is constricted by a lingual fissure and divided into two parts. The lingual part of the two is elongated labio-lingually, and its enamel layer of the mesial side is parallel to that of the distal side. On the other hand, the labial part forms a somewhat irregular annular enamel loop, which swells mesially and labio-distally. These swellings resemble the median sinus of the corresponding third plate of the pair specimen. In the fourth plate, the wear figure of the labial half shows a single enamel loop with a weak constriction by a labial fissure. The lingual part of the loop broadens mesio-distally, with an irregularly and roughly folded enamel layer. On the other hand, the wear figure of the lingual half shows two enamel loops divided by a lingual fissure. The lingual enamel loop of the two is longer labio-lingually than the labial one, and the enamel layer of its mesial side is parallel to that of its distal side. The shape of the labial enamel loop is somewhat similar to that of the corresponding part of the third plate. In the fifth plate, the lingual half wear figure consists of an oval enamel loop, a triangular enamel loop and an enamel ring. On the other hand, the labial half wear figure shows two 8-shaped enamel loops and an intermediate enamel ring. The 8-shaped enamel loop of the lingual side is pointed lingodistally, and that of the labial side is pointed labially. In the sixth plate, the lingual half wear figure consists of two enamel rings, and the labial half wear figure consists of two teardrop-shaped enamel loops and an intermediate enamel ring. The wear figure of the seventh plate consists of an enamel loop in the lingual half and three enamel rings in the labial half. The distal six plates and distal half plate are still unworn and covered with thick cement.

*M*³ (Unnumbered) —

Material and storage: Unnumbered specimen stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi (Plate 4, figs. 1-2).

Locality: Lingshang, Shangcun, Tunliu, Shanxi.

This specimen is a remarkably broad right *M*³ attached on a maxillary fragment. The molar is well worn and its mesial part is broken, so that only 11 plates and a distal half plate are preserved. The molar is slightly concave lingually in occlusal view. The abrasion surface is slightly twisted clockwise. The plates are moderately thick, and covered with thick cement. The cervical part of the molar is almost enwrapped by the broken maxillary fragment. The mesial plates are rather closely spaced, while the distal plates are moderately spaced in occlusal view. All the plates are slightly convergent abnormally

toward the labial side in occlusal view. The width of several distal plates is reduced toward the distal end of crown, and the greatest width of the plates is measured at the fourth plate. In most of the plates, the enamel is intensely folded in the median part, whereas it is roughly folded or smooth in the lateral part.

The first plate is badly broken, and only its labio-distal part is barely preserved. The lingual half of the second plate and the linguo-mesial part of the third plate are lost. The enamel layers of the first and second plates, and those of the second and third plates are linked with each other at their central parts. A rather small and obtuse distal median sinus is visible on the third plate. The wear figures of the fourth to eighth plates show only a large and irregular enamel loop. The labial ends of the third to fifth plates strongly curve and extend distally, whereas the labial and lingual ends of the sixth to eighth plates strongly curve and extend mesially. The central parts of the fourth to seventh plates are somewhat swollen mesio-distally. The small and acute median sinuses are visible in those swollen parts of the distal side of the fifth to seventh plates and the mesial side of the sixth plate respectively. The distal median sinus of the eighth plate is small and obtuse. The wear figure of the ninth plate is subdivided into a suboval labial enamel loop and a much larger and rather irregular lingual enamel loop by a labial fissure. In the lingual enamel loop, its lingual end is strongly pointed. The wear figure of the tenth plate is subdivided into seven relatively indistinct enamel rings. The 11th plate and the distal half plate are still unworn, and are covered with thick cement.

M_2 (SD77005) —

Material and storage: SD77005 stored in Shandong Provincial Museum, Jinan, Shandong (Plate 2, figs. 4-5).

Locality: Xuma, Nanwang, Penglai, Shandong.

This specimen is well worn large-sized left M_2 with six plates and a distal half plate. Its mesial half plate and some mesial plates are broken and lost. The crown is rather broad. The enamel layers are rather thick. The plates are thick, widely spaced, and covered with thick cement. The crown is slightly concave labially in occlusal view. The abrasion surface is separated into two parts by a blunt ridge running mesio-distally. In lateral view, both of the parts are similarly concave, but the labial part is more strongly concave than the lingual part in mesial and distal views. The plates are slightly convergent labially in occlusal view. The distal margin of the crown is convex in lateral view.

The first plate is strongly worn and poorly preserved. The wear figure of the second plate is subdivided into two closely connected enamel loops. The lingual enamel loop

with an irregular shape is much larger than the labial one. In the lingual enamel loop, the labial part is strongly swollen and moderately folded, whereas the lingual part is parallel-sided and only weakly folded. The swelling part is ascribed to the median sinus. The wear figure of the third plate strongly resembles that of the second plate. The wear figure of an earlier wear stage, typically developing in the fourth plate, is still observable in both of the second and third plates. The wear figure of the fourth plate shows the typical tripartite structure of two lateral enamel loops and a central annular enamel loop. The lingual enamel loop shows an elongated oval-shape and is concave mesially. The labial enamel loop is somewhat irregular. Its lingual part tapers lingually and its lingual end is acute and curves linguo-distally. The central enamel loop is nearly oval and moderately folded, and placed somewhat mesially to the two lateral enamel loops. The wear figure of the fifth plate is subdivided into two lateral enamel loops elongated labio-lingually and two subequal sized annular enamel loops. The wear figure of the sixth plate shows the tripartite structure composed of two subequal-sized labial enamel rings, a rather irregular central enamel loop and a lingual enamel loop. Both of the mesial and distal median sinuses are well developed in the lingual part of the central enamel loop. The two labial enamel rings are separated from the central enamel loop by a labial fissure. The distal half plate is slightly worn, and its distal part is partially broken. This half plate shows four mammillae in occlusal view.

M_3 (THP10.460) —

Material and storage: THP10.460 stored in Tianjin Natural History Museum, Tianjin (Plate 5, figs. 1-2).

Locality: Loc. 6, Haiyan, Yushe, Shanxi.

Horizon: Haiyan Formation.

See the original description by Teilhard de Chardin and Trassaert (1937). This molar is a well preserved left M_3 , with 14 complete plates and with a mesial and distal half plates. The molar is in an early stage of wear. It is remarkably large and has a rather long and broad crown. The plates are thick, and covered with thick cement. The crown is obviously concave labially in occlusal view, and twisted anti-clockwise. The abrasion surface is almost oval in occlusal view and slightly concave in lateral view. The height and width of several distal plates are strongly reduced toward the distal end of the crown. The plates are slightly convergent labially in occlusal view, and strongly convergent occlusally in lateral view. The cervical line is moderately concave occlusally in lateral view. The mesial half plate is deeply worn to be a rhombic enamel loop. Its labial end is acutely angled, and its distal enamel layer is

obtusely angled in its central part. The mesial half plate is merged with the first plate on the lingual side of the crown, whereas it is still detached on the labial side.

The wear figures of the first to third plates show only large transverse enamel loops, with their mesial and distal sides being approximately parallel. The distal median sinus is prominent and acute in the first and second plates, but more prominent and nearly semicircular in shape in the third plate. A small and acute mesial median sinus is visible in the second plate. The enamel layers are somewhat irregularly and roughly folded in the first to third plates. The wear figure of the fourth plate is subdivided into two closely adjoined enamel loops by a labial fissure. The labial enamel loop of the two has a rectangular shape with round corners, and is smaller than the lingual enamel loop. The labial part of the lingual enamel loop is somewhat swollen mesio-distally, with a prominent and obtuse distal median sinus and a much smaller mesial median sinus.

The wear figure of the fifth plate shows the tripartite structure of three enamel loops. Among the loops, the central one is subequal to the labial one. These are obviously shorter than the lingual one in the labio-lingual length. The labial part of the lingual enamel loop and the lingual part of the labial enamel loop are somewhat swollen distally. In the central enamel loop, the median part is somewhat constricted mesio-distally, and a prominent and obtuse distal median sinus is developed in the labial part. The wear figure of the sixth plate is divided into two lateral enamel loops and a central part composed of three large enamel rings with subequal sizes. Among the rings, the labial one has a swell of the median sinus on the distal side. The wear figures of the seventh and eighth plates are subdivided into five enamel loops and/or enamel rings. The most labial enamel ring of the seventh plate is somewhat shifted mesially. The ninth plate is in a beginning stage of wear. The tenth to 14th plates and the distal half plate are still unworn, and covered with thick cement. Five clear and parallel abrasion grooves run on the distal part of the abrasion surface.

M_3 (THP10.462) —

Material and storage: THP10.462 stored in Tianjin Natural History Museum, Tianjin (Plate 5, figs. 3-4).

Locality: Loc. 6, Haiyan, Yushe, Shanxi.

Horizon: Haiyan Formation.

See the original description by Teilhard de Chardin and Trassaert (1937). This molar is a right M_3 , which is the pair specimen of THP10.460 described above. Its general shape and form of lamellar subdivision strongly resemble those of its pair. The wear figures of the mesial

half plate and the first to fourth plates are very similar to those of the paired specimen, except that the distal median sinus is more prominent and obtuse in the first and second plates of the present molar. The wear figures of the fifth to eighth plates are also similar basically to those of the pair. The ninth to 14th plates and the distal half plate are still unworn, and covered with thick cement.

M_3 (Unnumbered) —

Material and storage: Unnumbered specimen stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi (Plate 4, figs. 3-4).

Locality: Lingshang, Shangcun, Tunliu, Shanxi.

This specimen is a moderately worn left M_3 with 15 plates. The mesial and distal ends of the crown are broken. The preserved first and last plates are not half plates but complete plates, so that the original number of the complete plates must be no less than 15. The plate formula is represented as +15+. This molar is remarkably large in size, rather long and has a remarkably broad crown. The crown concaves labially in occlusal view, and twists anti-clockwise. The abrasion surface is strongly concave in lateral view, and inclines to the lingual side. The enamel layers are finely wrinkled on most of the wear figures. The height and width of several distal plates are strongly reduced toward the distal end of the crown, and the greatest width is measured at the sixth plate. The plates are convergent occlusally in lateral view, and labially in occlusal view. The cervical line is moderately concave occlusally in lateral view.

The wear figure of the preserved part of the first plate is connected with that of the second plate at their lingual ends. The wear figures of the third to sixth plates show large ribbon-like transverse enamel loops. Each of the loops has a median sinus on the distal side. The median sinus is small and acute in the third plate, but is larger and rounder in the fourth and fifth plates. In the sixth plate, it is again small and obtuse. The wear figures of the seventh and eighth plates are subdivided into three parts by lateral fissures. In the case of the seventh plate, the division between the central and lingual parts is represented by the constriction attributable to the lingual fissure. Among the three parts, the lingual one is longest labio-lingually, while the labial one is shortest. The tripartite structure is nearly complete in the wear figure of the eighth plate, where a labial enamel ring, and elongated central and lingual enamel loops are observed. The central loop is slightly longer than the lingual one. The median fissure is traceable as a weak constriction in the central part of the wear figures of the seventh and eighth plates, and moreover, a small median sinus is also observed on each of the distal side of

those plates. In the second to eighth plates, the mesial and distal enamel layers are parallel to each other except for their central part. The ninth and tenth plates are slightly worn, and their wear figures consist of several enamel rings and/or enamel loops. The 11th to 15th plates are unworn.

*M*₂ or *M*₃ (Unnumbered) —

Material and storage: Unnumbered specimen stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing (Plate 6, figs. 1-2).

Locality: Qianjiashawa, Yangyuan, Hebei.

Horizon: The lower part of the Nihewan Formation.

This specimen is the mesial part of a left lower molar with seven plates. It is difficult to determine whether this molar is *M*₂ or *M*₃, because its mesial and distal parts are broken. The preserved part of the crown does not curve labially and lingually in occlusal view. The abrasion surface is slightly concave in lateral view. The plates are moderately thick and widely spaced, and covered with thick cement. They are nearly parallel to each other in occlusal view. In the plates preserved, the enamel layers are moderately folded in their central parts, whereas they are relatively smooth or only weakly folded in the lateral parts.

Each of the wear figures shows a single large transverse enamel loop in the second to fifth plates. The median part and lingual end of the loop are swollen in various degrees. The mesial and distal enamel layers are parallel to each other in the other parts of the loop.

Discussion

All the materials described above are exactly attributable to *Mammuthus* on the basis of the characters of the enamel figures. Among the materials, the specimen group of the four third molars and the second molar from Haiyan is evidently regarded as the typical *M. meridionalis* by the plate number and other measurements. The two molars from Tunliu are somewhat damaged and lack some plates and/or half plates. Their original plate numbers are, however, estimated to fall in the variation of *M. meridionalis*. Moreover the other measurements of the two molars also correspond to those of *M. meridionalis*. The two second molars from Penglai are also barely distinguishable morphologically from those of European *M. meridionalis*, whose measurements are given in van Essen (2003). The lower molar from Qianjiashawa is difficult to determine whether it is *M*₂ or *M*₃. But at any rate, the specimen is referable to *M. meridionalis* on the basis of the measurements except the plate number.

Some of the other specimens which are not described in this paper are also assignable to this species. The right

*M*₃ from Heshui (V.4760) has 11 complete plates (Research Group for the Huanghe Elephant, 1975). 78DL01 from Dali is composed of a complete set of four third molars with 11 complete plates (Wang, 1988). V.4760 and 78DL01 are referable to the earliest stage of *M. meridionalis*. 78DL02 from Dali is composed of a complete set of four second molars with the unerupted third molars. Among them, the upper second molars have eight complete plates and the lower ones have nine complete plates. These plate numbers also correspond to the lower limit of the plate number of European *M. meridionalis* (van Essen, 2003). The left *M*₃ from Pingliang (No.1001) shows a very low value of LF (3.8). This value is as low as that of *M. rumanus*. But No.1001 is identified with *M. meridionalis*, because it has 13 plates or more. Its low LF value is attributable to its large size (Lister and Joysey, 1992). The left *M*₃ from Mengyin (V.2610) has nine plates, and lacks its mesial part and distal end. But V.2610 is also referable to *M. meridionalis* on the basis of its lamella frequency and enamel thickness. The left *M*₂ or *M*₃ from Qianjiashawa with only seven plates, is also identified with *M. meridionalis*, because its lamella frequency and enamel thickness fall into the variation of *M. meridionalis*.

Mammuthus trogontherii (Pohlig, 1885)

Selected synonyms

- Elephas trogontherii*; Pohlig 1885, *Zeitschr. deutsch. geol. Ges.*, **37**, 1027: 1888, *Nova Acta Leop.Carol.*, **53**, (1), 193, fig. 79: 1891, *Nova Acta Leop.Carol.*, **57**, (5), 195, fig.82.
- Elephas intermedius*; Jourdan 1891, *C. R. Acad. Sci. Paris*, **53**, 1013.
- Elephas nestii*; Pohlig 1891, *Nova Acta Leop.Carol.*, **57**, (5), 303; Osborn 1942, *Proboscidea*, Vol. II, 1059-1060, fig.941.
- Elephas wüstii*; Pavlow 1910, *Nouveaux Mem. Imp. des Natural de Moscou*, **27**, (2), 6, pl. 1, figs. 1, 2.
- Elephas antiquus trogontheroides*; Zuffardi 1913, *Palaeont. Ital.*, **19**, 130, pl. 9 (III).
- Parelephas trogontherii* Pohlig; Guenther 1969, *Paläont. Abh. Ser. A*, **3**, (3/4), 714-731, pl. 50, figs. 4-6: pls. 51-61.
- Mammuthus armeniacus* (Falconer); Maglio 1973 (in part), *Trans. Amer. Phil. Soc.*, **63**, 57-60, pl. 18, fig. 1.
- Mammuthus (Parelephas) trogontherii* Pohlig; Chow and Chang 1974, *Chinese Proboscidean Fossils*, p. 57-58, pl. 25, figs. 1, 2.
- Archidiskodon planifrons* (Falconer et Cautley); Chia and Wang 1978 (in part), *Hsihoutu*, 9-11, pl. 4, figs. 1A, 1B.
- Palaeoloxodon cf. namadicus* (Falconer et Cautley); Chia and Wang 1978 (in part), *Hsihoutu*, 11-12, pl. 3, figs. 3, 4.
- Palaeoloxodon tokunagai* Matsumoto; Tang *et al.* 1983, *Vertebrata PalAsiatica*, **21**, 80, pl. 1, fig. 14.
- Palaeoloxodon* sp.; Wei *et al.* 1985, *Acta Anthrop. Sinica*, **4**, 227, pl. 1, fig. 4.
- Palaeoloxodon* sp.; Tang *et al.* 1995, *Vertebrata PalAsiatica*, **33**, 79, pl. 1, fig. 3.

Diagnosis

M^3 and M_3 with 17 to 22 plates; plates rather thin and lamella frequency high (4-8); enamel layer thin; hypsodonty index rather high.

Description

M^3 (Unnumbered) —

Material and storage: Unnumbered specimen stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing (Plate 6, figs. 5-6).

Locality: Pinglu, Shanxi.

This specimen is a right M^3 in an early stage of wear, which has 17 plates, and a mesial and distal half plates. The crown is rather long, high and narrow. The plates are relatively thin mesio-distally. The crown is slightly concave lingually in occlusal view. The abrasion surface is convex in lateral view. Both of the width and height of several distal plates gradually decrease toward the distal end of the crown. The greatest width is measured at the fourth plate. The plates are slightly convergent lingually in occlusal view and cervically in lateral view. Some of the plates are weakly concave mesially or show a weakly curved S-shape in labial view. The enamel is generally smooth, and only roughly waved on some wear figures.

The mesial half plate is severely broken, and its lower part is exclusively preserved. The first plate is also broken in their labial and lingual sides. The wear figure of the second plate shows a large transverse enamel loop with a rather irregular shape. The lingual end of the plate is broken. The mesial enamel layer of the plate curves wavelike. It points distally in some parts and swells mesially in other parts. The distal enamel layer also curves wavelike in the same manner. In the enamel layers, the median part is most strongly pointed or swelled. The wear figure of the third plate consists of an enamel loop slightly damaged at the lingual end. It is nearly straight labio-lingually, and divided into three parts by two constrictions. Among the three parts, the lingual one is longer labio-lingually than the other two parts with nearly the same size. A prominent but obtuse distal median sinus is developed in the central part. The wear figure of the fourth plate shows the tripartite structure of three sub-equal enamel loops. Among them, the central one is slightly longer labio-lingually than the lateral two. The lateral loops are nearly rectangular with round corners, whereas the central one is weakly constricted in its central part, and has a small and round distal median sinus. The wear figure of the fifth plate is also divided into three parts. Among the three, the central part is longest labio-lingually, and subdivided into an elliptical enamel loop and two enamel rings. Each of

the lateral parts is composed of an enamel loop. The wear figure of the sixth plate is subdivided into a sub-oval enamel loop and six enamel rings with different sizes. The seventh plate is just in a beginning stage of wear, while the eighth to 17th plates and the distal half plate are still unworn.

Mandible (V.2849) —

Material and storage: V.2849 stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi (Plate 8, figs. 1-3).

Locality: Xihoudu (Hsihoudu), Ruicheng County, Shanxi.

Horizon: Xihoudu Formation.

The original description of the specimen was given by Chia and Wang (1978). This specimen is represented by a left mandible with a well preserved M_2 and M_3 . The mandible includes its symphyseal part, but the anterior margin of the mandibular body, the tip of the symphysis, and the coronoid process are lost. The condyle is somewhat damaged.

In lateral view, the symphyseal part projects antero-ventrally. The ventral margin of the mandibular body is slightly concave in its anterior part, and almost straight in its middle part and gradually ascends in its posterior part. The mandibular angle is roundly convex. The posterior margin of the ascending ramus is also convex posteriorly. The ramus, as a whole, connects with the mandibular body at right angles. The preserved part of the anterior margin of the ramus is slightly concave. The alveolar margin is nearly straight in labial view, whereas it is remarkably concave in medial view. The mandibular foramen is large, but no molar is observed inside the foramen.

Dp_4 (V.6753) —

Material and storage: V.6753 stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing (Plate 6, figs. 3-4).

Locality: Liangjiapo, Linyi, Shanxi.

Horizon: Sanmen Formation.

The original description of this specimen was given by Tang *et al.* (1983). This specimen is a well-preserved right Dp_4 with ten plates and a mesial half plate, which is in an early stage of wear. This molar is rather small. The plates are thin and closely spaced. The enamel layers are generally smooth, and are only roughly folded or finely wrinkled in some wear figures. The crown is obviously concave labially in occlusal view. The greatest width is measured at the eighth plate, which is placed near the distal end of the crown. The plates are convergent labially in occlusal view. In lateral view, the unworn distal three plates (the eighth to tenth plates) are convex distally in lateral and occlusal view, and their apexes are convergent

occlusally.

The mesial half plate lies in the labial half of the mesial margin of the crown. It is much smaller and thinner than the succeeding plates. Its lingual part is merged with the first plate, whereas it is still detached on the labial side. The wear figure of its labial part consists of two small enamel rings, which are closely connected. The lingual part of the first plate is lost by the contact with the preceding Dp_3 . The wear figure of the first plate shows a well-worn enamel loop. Its labial and central parts are expanded mesio-distally, and the enamel loop is strongly constricted between these expanded parts. Its lingual part is narrow mesio-distally and strongly pointed lingually. The wear figure of the second plate is divided into two enamel loops, which contact with each other in the central part of the crown. These loops are sub-equal in labio-lingual length. The lingual part of the lingual enamel loop is slightly swollen mesially. The lingual part of the labial enamel loop bends distally to form a distal median sinus. The wear figure of the third plate shows a large transverse enamel loop. Its central part is obviously swollen mesio-distally, whereas both of the mesial and distal sides are approximately parallel to each other in the labial and lingual parts. The labial end of the loop is semicircular, but its lingual end extends distally. The wear figure of the fourth plate shows the tripartite structure of three enamel loops. All of them are sub-equal in labio-lingual length. The labial part of the lingual enamel loop is somewhat swollen mesio-distally, while the lingual part of the labial enamel loop is swollen only distally. A prominent median sinus is developed on the mesial and distal sides of the central enamel loop. The wear figure of the fifth plate is divided into two lateral enamel loops and three central enamel rings. The labial enamel loop is nearly semicircular, and much smaller than the lingual one. The labial part of the lingual enamel loop is slightly swollen mesio-distally. In the three central enamel rings, the most labial one is largest and sited distally than the other two rings. The wear figure of the sixth plate is also divided into three parts by two lateral fissures. Labio-lingually compressed low mammillae are observed in the fissures. The central part consists of four enamel rings. Among them, the medial two rings are somewhat compressed labio-lingually, and much smaller than the other two enamel rings. Each of the labial and lingual parts consists of a single enamel ring. The seventh plate is in an initial stage of wear, so that only two lateral and four central mammillae are observed on the abrasion surface. The eighth to tenth plates are still unworn and mostly covered with cement.

M_2 (V.2849) —

Material and storage: V.2849 stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi (Plate 7, fig. 1).

Locality: Xihoudu (Hsihoudu), Ruicheng County, Shanxi.

Horizon: Xihoudu Formation.

The specimen is a strongly worn left M_2 with five plates and a distal half plate. Its mesial part is lost by abrasion. The abrasion surface of the molar shows acute angles with the plates in lateral view, so that enamel layers on the surface appear to fold more intensely than they actually do. The plates are slightly convergent labially in occlusal view, and their lingual halves are arranged more mesially than their labial halves.

In the mesial part of the crown, two "reversed" enamel loops are formed to join the enamel layers of adjacent plates. One of them consists of the labio-distal enamel layer of the first plate and the labio-mesial enamel layer of the second plate, and another one consists of the linguo-distal enamel layer of the second plate and the linguo-mesial enamel layer of the third plate. The enamel layer of the other part of the second plate is continuous with the enamel layer of the third plates. The wear figure of the fourth plate shows a stair-like shape, with its lingual part shifting more mesially than its labial part. The enamel layers of the distal and mesial sides of the labial half are convex distally in its lingual part. The wear figure of the fifth plate is divided into a small enamel ring, a triangular enamel loop, and a much larger irregular enamel loop. The enamel layer of the lingual enamel loop shows an intensive indentation in the mesial side of its labial part. The slightly worn distal half plate is observable only at the linguo-distal corner of the crown. The other part of the half plate is hidden owing to tight contact of M_2 with M_3 .

M_3 (V.2849) —

Material and storage: V.2849 stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi (Plate 7, fig. 1).

Locality: Xihoudu (Hsihoudu), Ruicheng County, Shanxi.

Horizon: Xihoudu Formation.

The specimen is a slightly worn left M_3 planted on the mandible behind the left M_2 described above. A mesial half plate and 11 plates are observable and the other plates are hidden distally in the mandible. In occlusal view, the crown is slightly concave labially, and the plates are slightly convergent labially. The plates are thin and widely spaced, and are covered with thick cement. The enamel layers are generally smooth, and are only weakly folded in some wear figures.

The mesial half plate appears only in the central part of the mesial end of the crown. The other part of the half plate is hidden below the mesial border of the crown

tightly contacting with M_2 . The half plate is in an early stage of wear, so that only the apexes of several mammillae with different sizes are slightly worn. The wear figure of the first plate is divided into three parts arranged disorderly. The labial part of the plate is composed of two enamel rings and an enamel loop. Among them, the labial enamel ring is strongly compressed labio-lingually and much smaller than the circular lingual ring. The enamel loop between them shows a roundly triangular shape, and its mesio-distal width gradually decreases toward its labial end. The central part of the plate shows the wear figure of a large enamel ring, which shifts more distally than those of the lingual and labial parts of the plate. Its enamel layer has a tiny protrusion on its labio-distal side. The wear figure of the lingual part is composed of a large enamel loop with a zigzag margin and a much smaller lingual enamel ring. The wear figure of the second plate is divided into two parts by a wide median fissure. The labial part is composed of a labial enamel loop and two different-sized enamel rings. The lingual part of the enamel loop is strongly pointed distally. The smaller enamel ring of the two is located at the linguo-distal side of the larger one. The lingual part of the plate is composed of a large semicircular enamel ring and a boomerang-shaped enamel loop. The wear figure of the third plate is divided into three parts by two lateral fissures. The central part is composed of four enamel rings, which are partially merged with each other. Among them, the second labial ring is elongated mesio-distally and remarkably shifted more distally than the other three enamel rings. The distally shifted enamel rings in the central parts of the first to third plates represent the distal median sinuses of the plates in the course of abrasion. The wear figure of the fourth plate is composed of seven enamel rings that are arranged in a doglegged line. The fifth and sixth plates are at an initial stage of abrasion. The seventh to 11th plates are still unworn, and covered with thick cement.

M_3 (T1-C 83-10-12) —

Material and storage: T1-C 83-10-12 stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing (Plate 7, figs.2-3).

Locality: T1-C, Donggutuo site, Yangyuan County, Hebei.

Horizon: The uppermost part of the Nihewan Formation.

This specimen is a moderately worn left M_3 with 17 plates. Its mesial end is lost by abrasion and breakage. As regards its distal end, some plates and/or a distal half plate are lost. This molar is relatively large and high crowned. The plates are thin, covered with thick cement, and moderately spaced in occlusal view. The crown is slightly concave labially and somewhat twists anti-clockwise. The abrasion

surface shows an elliptical shape in occlusal view. It is slightly concave in lateral view, and inclines lingually. The plates are slightly convergent labially in occlusal view, while they are strongly convergent occlusally in lateral view. In lateral view, most of the plates are convex mesially from the cervical part to the middle part, while the distal plates are concave mesially in their occlusal part. The width and height of several distal plates are strongly reduced toward the distal end of the crown. The cervical line is strongly concave occlusally in lateral view. The enamel layers are generally smooth, and only finely wrinkled in some wear figures.

The first plate preserved is strongly damaged, so that its morphological characters cannot be observed. The labial and lingual parts of the second plate are considerably broken. Its wear figure shows a single large transverse enamel loop. The wear figure of the third plate shows a large irregular transverse enamel loop. Its median part is obviously swollen, whereas the mesial and distal sides of its labial and lingual parts are approximately parallel to each other. The wear figures of the fourth and fifth plates show large transverse enamel loops. Their median parts are slightly swollen mesio-distally, whereas the lingual and labial parts are parallel-sided as in the third plate. Each of the enamel loops is strongly constricted between its central and labial parts. Small distal median sinuses are visible in the fourth and fifth plates. They are somewhat pointed. The wear figure of the sixth plate is divided into two closely connected enamel loops by a lateral fissure. The labial loop is parallel-sided and much smaller than the lingual one. The labial part of the lingual enamel loop resembles the central part of the fourth and fifth plates in its swollen shape, and has a somewhat obtuse distal median sinus. The wear figure of the seventh plate also consists of two enamel loops. The labial enamel loop is parallel-sided and concave mesially. The lateral fissure between the two enamel loops is much wider than that of the sixth plate. The lingual enamel loop is constricted with the lingual lateral fissure. A blunt median sinus is observed as a slight swelling at the labial end of the lingual enamel loop, where a weak constriction is present on its lingual side. The lingual part of the lingual enamel loop is longer labio-lingually than its labial part and the labial enamel loop. The wear figure of the eighth plate is divided into three enamel loops. Among them, the central one is longest labio-lingually, and the labial one is shortest. All the loops are parallel-sided, and the lingual loop is concave mesially. The central part of the central enamel loop is slightly constricted mesio-distally. The labial lateral fissure is very wide as in the seventh plate. The wear figure of the ninth plate also consists of the three parts. They are a labial

enamel ring, a lingual enamel loop, and a central enamel loop that is the longest of the three, and its central part is slightly constricted. The apex of the tenth plate is damaged, so that its wear figure is indistinct. The 11th plate is only slightly worn. Only three enamel rings and three mammillae are visible on its apical part. The 12th plate is unworn, and only five mammillae are observed on its apical part. The 13th to 17th plates are still unworn and covered with cement.

Discussion

Many authors have adopted the species name *M. trogontherii* for the mammoth species morphologically intermediate between the more primitive species *M. meridionalis* and the more advanced species *M. primigenius* in Eurasia (e.g., Beden and Guérin, 1975; Lister, 1996 and Lister and Sher, 2001). On the basis of its priority, Aguirre (1968, 1969) and Maglio (1973) regarded *armeniacus* as a senior synonym of *M. trogontherii*. But in this paper, we follow the opinion to use *M. trogontherii* rather than *M. armeniacus* for the Eurasian steppe mammoth, because Adam (1988) claimed that we had insufficient morphological grounds even for synonymizing *M. armeniacus* with *M. trogontherii*, and suggested that the type of *M. armeniacus* might represent a westerly population of Asian elephant, *Elephas maximus*.

On the basis of abundant remains of *M. trogontherii* from Europe, especially those from Süssenborn, the type locality of the species, Lister and Joysey (1992) and Lister (1996) determined the plate formula of M3 as x17-21x. The remains of *M. trogontherii* newly discovered from the Early Olyorian of northeastern Siberia indicate that the maximum plate number of M3 attains to 22 (Lister and Sher, 2001; Lister *et al.*, 2005).

As described above, the two third molars from Pinglu and from the Nihewan Formation at the Donggutuo site are apparently referable to *M. trogontherii* by their distinct morphological characters, as well as their plate number and other metric data. Although the third molar from Xihoudu is in an the early stage of eruption, and its considerable part is hidden in the mandible, its plate number is estimated to be seventeen or more judging from its visible part. The other mammoth materials from the Nihewan Formation at the Goudi site are also referable to *M. trogontherii* on the basis of their distinct morphological characters and measurements (Wei *et al.*, 2003). The materials from this site belong to the earliest evolutionary stage of *M. trogontherii*.

Apart from the third molars, V.6753 from Linyi, and V.2843 and V.2844 from Xihoudu (Table 2) are also identified with *M. trogontherii* by their morphological characters and measurements consistent with those of

the remains from Süssenborn (Guenther, 1969). The fragmental or severely worn molars from the Xiaochangliang site (Tang *et al.*, 1995) and Donggutuo site (Wei *et al.*, 1985) are also referable to *M. trogontherii* despite their poor preservation, because they have high lamella frequency.

Mammuthus rumanus and/or *Mammuthus meridionalis*

Remarks

The four molars from the Yushe Basin (THP 31.132, 30.803, 18.898, 10.456) possibly belong to the primitive mammoth, and are referred to the first and/or second molars by their dimensions (Table 2). But the enamel layers of the molars are rather thick and their lamella frequencies are too small for the first or second molar of *M. meridionalis*. It is difficult to determine the plate numbers of the molars, because they are more or less damaged. Additionally, the measurements of the first and second molars of *Mammuthus rumanus* are not available for comparison with the four molars. Thus the taxonomic position of the molars is tentative.

Mammuthus sp. indet.

Description

*Dp*³ (Unnumbered) —

Material and storage: Unnumbered specimen stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing (Plate 8, fig. 4).

Locality: Loc. 81018, Gaoya, Tianzhen, Shanxi.

This specimen is an upper molar with three plates and a distal half plate. Its mesial part is broken and some plates must be lost, so that the original number of plates cannot be determined. This molar is probably referred to a right DP³ by its size. The plates are moderately thick and closely spaced. The enamel layers are thin. They are roughly folded in the central part of the crown, but are weakly folded or smooth in the lateral parts.

The first plate is considerably broken in its lingual part. Its wear figure probably consists of a single enamel loop, which is constricted mesio-distally in its central part, and swells distally in its labial part. The wear figure of the second plate shows a large transverse enamel loop, in which the lingual part apparently shifts more mesially than the labial part. The mesial median sinus is large and obtuse. The wear figure of the third plate is divided into two sub-equal enamel loops. The enamel layers of their mesial side are parallel to those of the distal side. The

lingual enamel loop shifts more mesially than the labial enamel loop which is somewhat broken. The former loop is concave mesially, while the latter loop is slightly concave distally. The distal half plate is small, and lies at the disto-lingual end of the crown. It is closely connected to the labial enamel loop of the third plate in occlusal view.

Dp⁴ (Unnumbered) —

Material and storage: Unnumbered specimen stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing (Plate 8, figs. 5-6).

Locality: Loc. 81018, Gaoya, Tianzhen, Shanxi.

This specimen is probably a right Dp⁴ that has three mesial plates and a mesial half plate. It can be contacted with the preceding right Dp³ described above. This molar is in an early stage of wear. The plates are covered with thick cement.

Remarks

The two deciduous premolars described above, two molars from Linyi (V.2308 and V.3044: Chow and Chow, 1959; 1965), and a molars from Tanchen (Chow, 1961) are probably referable to the genus *Mammuthus* by their characters of the enamel figures. Among the cheek teeth, V.2308 and V.3044 were originally assigned to *Archidiskodon* cf. *planifrons* and *A. sp.* respectively. The molar from Tanchen was also referred to *A. sp.* by the original author. But, it is impossible to identify them in specific level, because the premolars are extremely fragmental, and the molars are severely worn.

5. Discussion

On the basis of the detailed systematic descriptions in the preceding chapter, we recognize the three species, *M. rumanus*, *M. meridionalis* and *M. trogontherii*, in the primitive mammoth remains from northern China. The three species can be distinguished from each other by the number of the molar plates, and by the other minor characters of the molars including the hypsodonty. Among the three, the number and hypsodonty are lowest in *M. rumanus*, intermediate in *M. meridionalis*, and highest in *M. trogontherii*. These indicate a general evolutionary trend in elephant molars from primitive to advanced conditions. Namely, *M. rumanus*, *M. meridionalis* and *M. trogontherii* show the most primitive, intermediate and most advanced conditions respectively (Fig. 6).

As regards the chronological distribution of the three species, we select the reliable fossil records dated paleomagnetically from the many records of the primitive mammoths of northern China as shown in Chapter 3. The

selected records are those from the localities in the Nihewan and Yushe Basins, and Xihoudu.

Among the localities in the Yushe Basin, Liyucun is recorded to yield the molar numbered THP18.906 which is allocated to *M. rumanus* herein. The sediments yielding the molar is considered to be the Mazegou Formation which is roughly dated between 3.4 Ma and 2.8 Ma (Fig. 4). Thus *M. rumanus* is placed in this time interval, although its exact age cannot be determined within the interval (Fig. 6).

Haiyan in the same basin yields the five molars (THP 10.464, 10.459, 10.461, 10.460 and 10.462) which are assigned to *M. meridionalis* herein. The fossil-bearing sediments at Haiyan belong to the Haiyan Formation which is roughly dated between 2.5 Ma and 1.9 Ma (Fig. 4). Thus *M. meridionalis* is placed somewhere in the time interval between 2.5 Ma and 1.9 Ma. The unnumbered molar from Qianjiashawa in the Nihewan Basin is allocated to *M. meridionalis* herein. The molar occurred from the lower part of the Nihewan Formation, which is roughly dated between 2.6 Ma and 1.8 Ma. This time interval is approximately consistent with the above-mentioned interval determined in the Haiyan Formation (Figs. 4, 6).

Xihoudu, and the localities in the Nihewan Basin except Qianjiashawa yield the mammoth molars accurately dated by the paleomagnetic method. All the molars are assigned to *M. trogontherii* herein, and therefore the biostratigraphic range of *M. trogontherii* can be determined accurately as 1.66 Ma to 1.1 Ma (Fig. 6).

As regards the European records of the primitive mammoths, Lister *et al.* (2005) noted that *M. rumanus* and *M. meridionalis* range from 3.5 Ma to 2.5 Ma, and from 2.6 Ma to 0.7 Ma, respectively. The above-mentioned ranges of *M. rumanus* and *M. meridionalis* roughly determined in northern China fall in the range of each species in Europe. Thus *M. rumanus* was possibly present in northern China during nearly the same time as in Europe. If we accept the theory of Maglio (1973) that the genus *Mammuthus* originated in Africa, it is likely that *M. rumanus* migrated from Africa or Europe to northern China in the interval of 3.4-2.8 Ma, the age of the Mazegou Formation.

In Europe, *M. trogontherii* appeared 1.0 Ma, whereas it appeared in the interval of 1.2-0.8 Ma in Northeast Siberia (Lister *et al.*, 2005). As briefly pointed out by Wei and Lister (2005), *M. trogontherii* shows its earliest appearance in northern China at 1.66 Ma, the age of the Goudi site. Thus we can believe that *M. trogontherii* indigenously evolved from *M. meridionalis* in northern China around the Plio-Pleistocene boundary (Fig. 6), and

then spread to Northeast Siberia (around 1.2 Ma or somewhat later), and to Europe (somewhat earlier than 1.0 Ma).

6. Conclusion

The cheek teeth of the genus *Mammuthus* can be distinguished from the other representative genera of the elephantids, such as *Palaeoloxodon*, *Elephas* and *Loxodonta*, by using the diagnostic characters given in p.67. We have selected the remains certainly referable to *Mammuthus* from many elephantid remains obtained from the Pliocene and Lower Pleistocene of northern China. All the selected remains are assignable to the primitive mammoths clearly distinct from the woolly mammoth, *Mammuthus primi-*

genius, of the Late Pleistocene. In the remains of the primitive mammoths, we recognize such three species as *M. rumanus*, *M. meridionalis* and *M. trogontherii*. They are distinguished from each other mainly by the number of plates in M^3 and M_3 (see the key given in p.69).

Among the fossil localities yielding the primitive mammoths, the paleomagnetically dated localities are exclusively considered in order to clarify the biostratigraphic distribution of the three species. The most primitive species of the three, *M. rumanus*, occurs from the Mazegou Formation of the Yushe Group roughly ranging from 3.4 Ma to 2.8 Ma. The intermediate species, *M. meridionalis*, also occurs from the Haiyan Formation of the same group roughly ranging from 2.5 Ma to 1.9 Ma, and from the lower part of the Nihewan Formation roughly ranging from

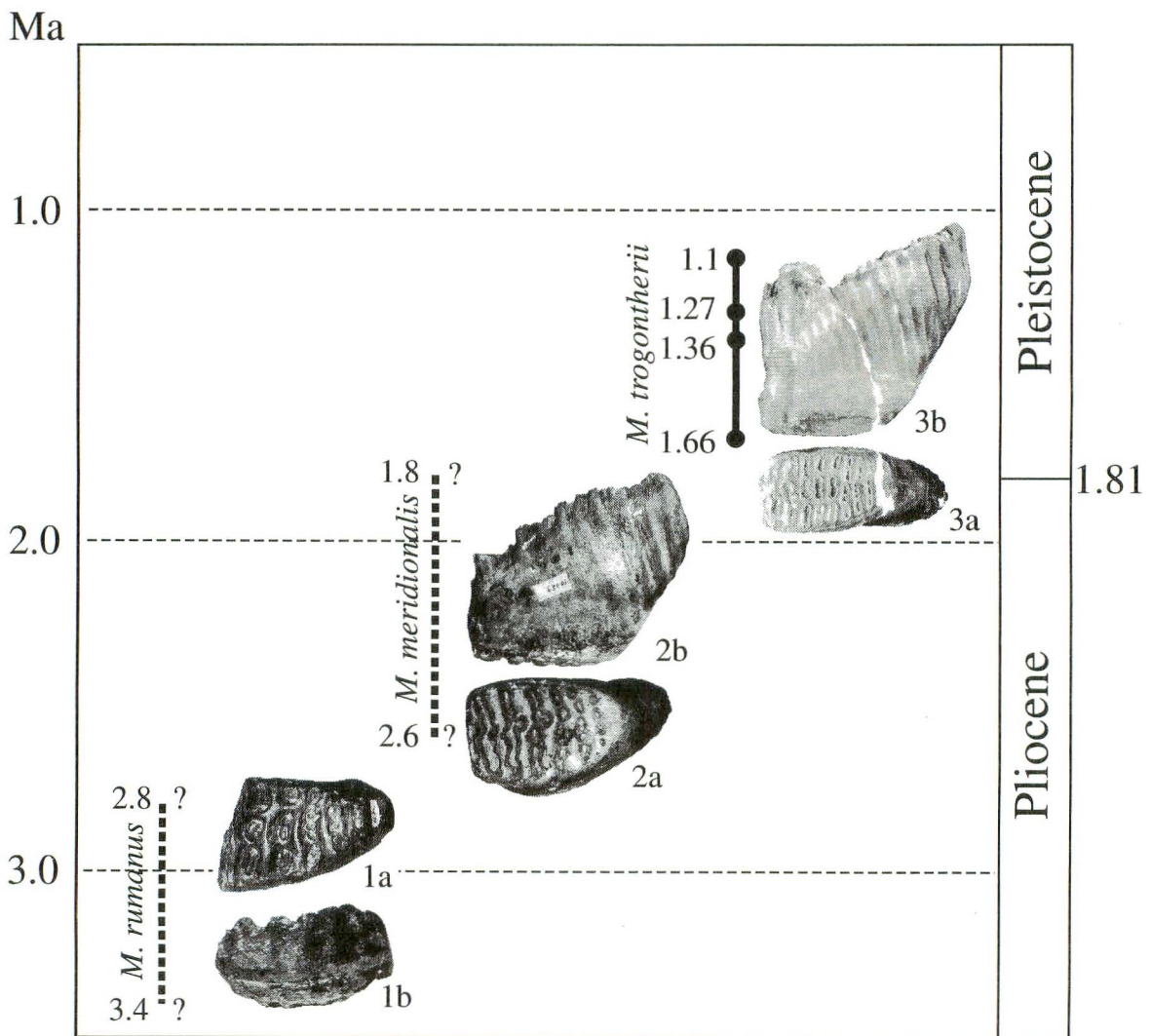


Fig. 6 Biostratigraphic relationship among the three primitive mammoth species in northern China. Differences in dental morphology are also shown among three species. 1: right M_3 numbered THP18.906 (1a: occlusal view, 1b: lingual view), 2: right M^3 numbered THP10.459 (2a: occlusal view, 2b: lingual view), 3: left M^3 numbered V.13610 (3a: occlusal view, 3b: buccal view), which was described by Wei *et al.* (2003).

2.6 Ma to 1.8 Ma. The most advanced species, *M. trogontherii*, is obtained from the horizons dated from 1.66 Ma to 1.1 Ma in the Nihewan Formation and at the Xihoudu site. Consequently *M. rumanus*, *M. meridionalis* and *M. trogontherii* lived in northern China in some period between 3.4 Ma and 2.8 Ma, in some period between 2.6 Ma and 1.8 Ma, and in the period between 1.66 Ma and 1.1 Ma, respectively. *M. rumanus* possibly migrated from Africa or Europe in the middle Pliocene. On the other hand, *M. trogontherii* probably evolved from *M. meridionalis* indigenously in northern China, because the first appearance of *M. trogontherii* (1.66 Ma) is the earliest in Eurasia.

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Explanation of Plate 1

Mammuthus rumanus (Ștefănescu, 1924)

Figs. 1-2: Left M^3 from Qinxian (unnumbered cast), stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

- 1: Labial view.
- 2: Occlusal view.

Figs. 3-4: Right M_3 from Liyucun, Yushe (THP18.906), stored in Tianjin Natural History Museum, Tianjin.

- 3: Occlusal view.
- 4: Lingual view.

Scale bar = 10cm

Plate 1



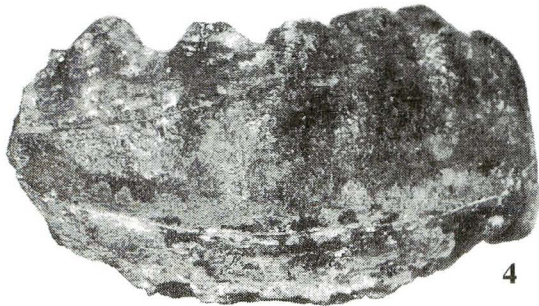
1



2



3



4



Explanation of Plate 2

Mammuthus meridionalis (Nesti, 1825)

Figs. 1-2: Right M^2 from Xuma, Nanwang, Penglai (SD77004), stored in Shandong Provincial Museum, Jinan, Shandong.

1: Lingual view.

2: Occlusal view.

Fig. 3: Left M^2 from Haiyan, Yushe (THP10.464), stored in Tianjin Natural History Museum, Tianjin.
Occlusal view.

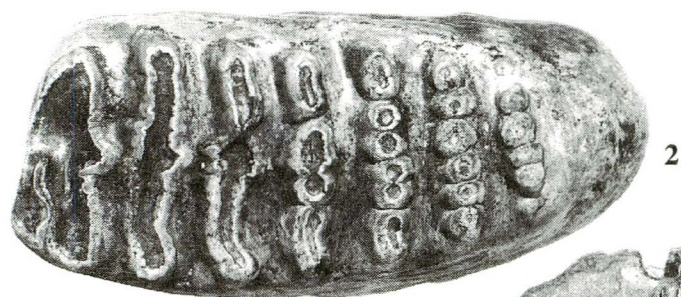
Figs. 4-5: Left M_2 from Xuma, Nanwang, Penglai (SD77005), stored Shandong Provincial Museum, Jinan, Shandong.

4: Occlusal view.

5: Labial view.

Scale bar = 10cm

Plate 2



Explanation of Plate 3

Mammuthus meridionalis (Nesti, 1825)

Figs. 1-2: Right M³ from Haiyan, Yushe (THP10.459), stored in Tianjin Natural History Museum, Tianjin.

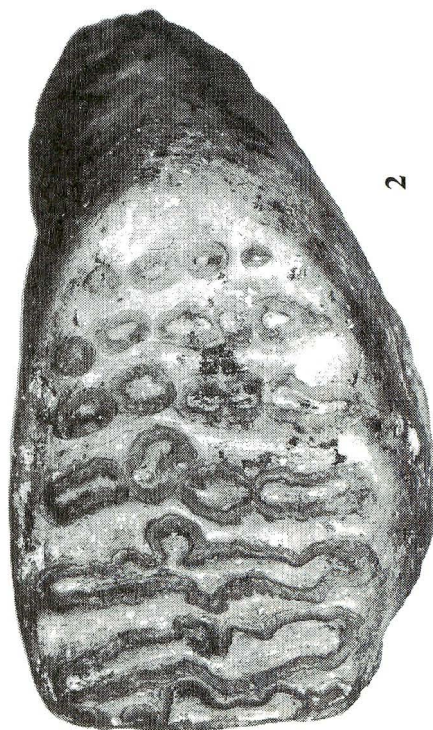
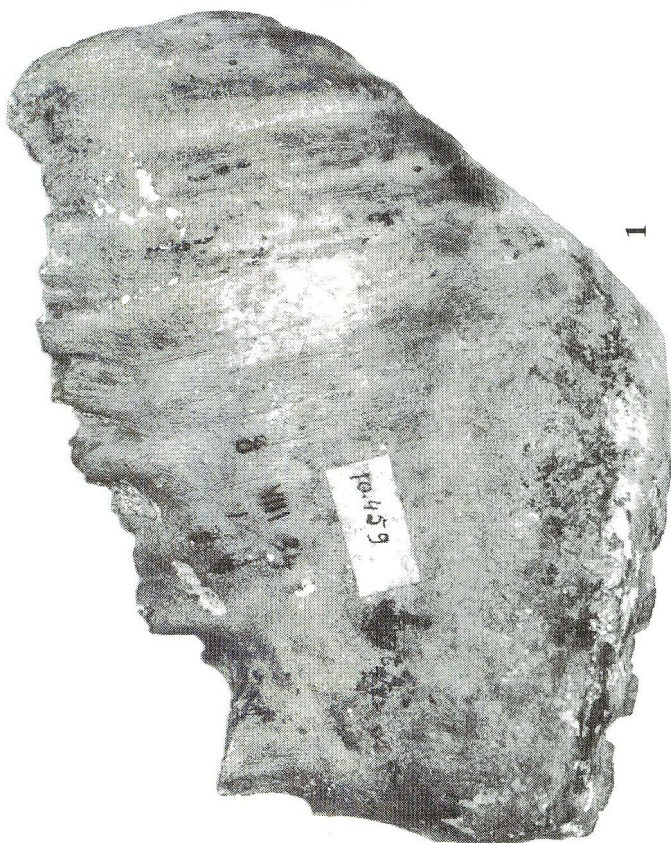
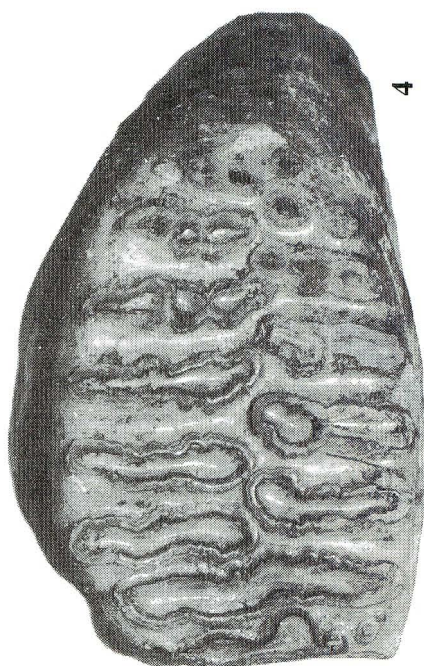
- 1: Lingual view.
- 2: Occlusal view.

Figs. 3-4: Left M³ from Haiyan, Yushe (THP10.461), stored in Tianjin Natural History Museum, Tianjin.

- 3: Labial view.
- 4: Occlusal view.

Scale bar = 10cm

Plate 3



Explanation of Plate 4

Mammuthus meridionalis (Nesti, 1825)

Figs. 1-2: Right M^3 from Lingshang, Shangcun, Tunliu (unnumbered), stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi.

- 1: Labial view.
- 2: Occlusal view.

Figs. 3-4: Left M_3 from Lingshang, Shangcun, Tunliu (unnumbered), stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi.

- 3: Occlusal view.
- 4: Labial view.

Scale bar = 10cm

Plate 4



Explanation of Plate 5

Mammuthus meridionalis (Nesti, 1825)

Figs. 1-2: Left M_3 from Haiyan, Yushe (THP10.460), stored in Tianjin Natural History Museum, Tianjin.

1: Occlusal view.

2: Labial view.

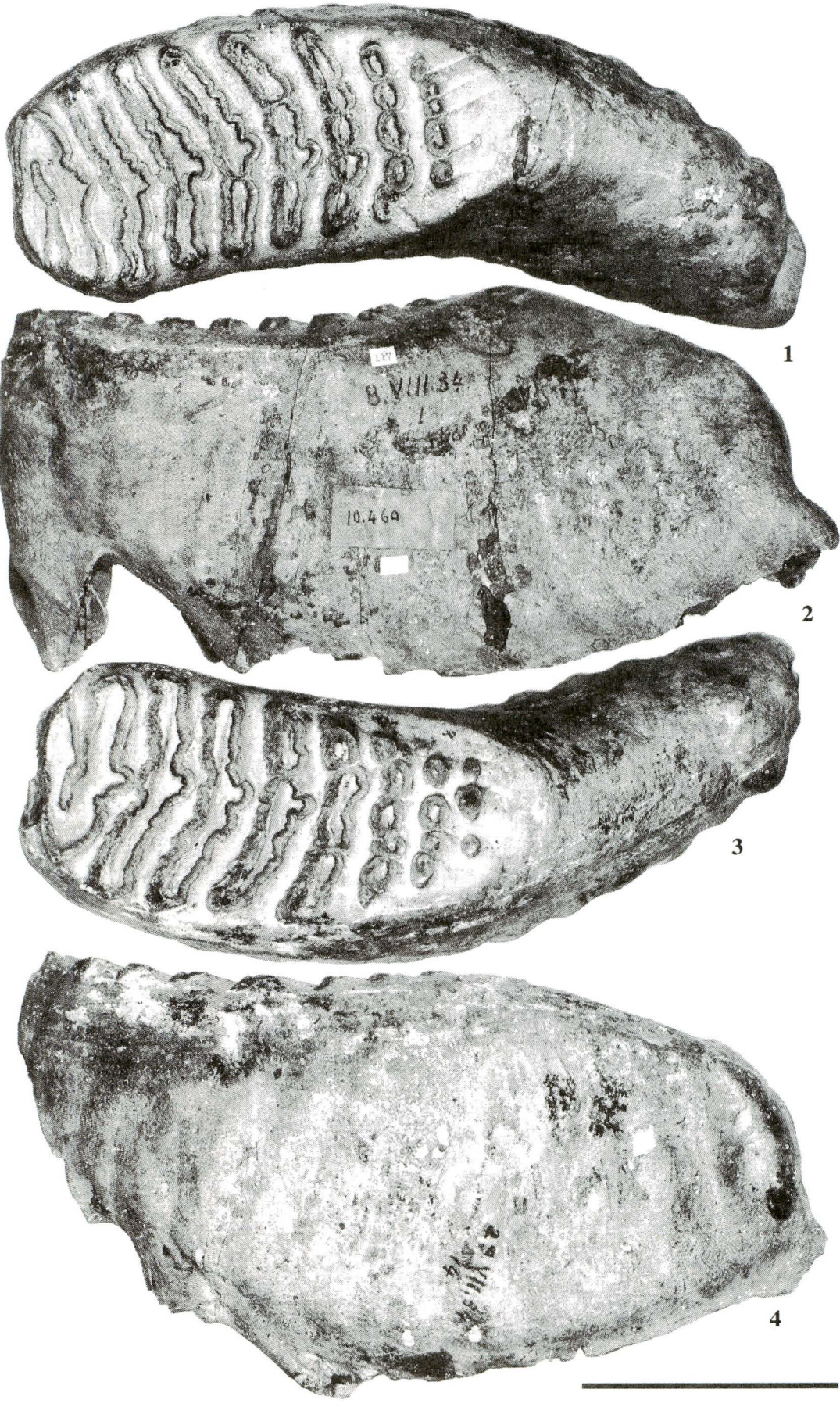
Figs. 3-4: Right M_3 from Haiyan, Yushe (THP10.462), stored in Tianjin Natural History Museum, Tianjin.

3: Occlusal view.

4: Lingual view.

Scale bar = 10cm

Plate 5



Explanation of Plate 6

Mammuthus meridionalis (Nesti, 1825)

Figs. 1-2: Left M_2 or M_3 from Qianjiashawa (unnumbered), stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

1: Occlusal view.

2: Labial view.

Mammuthus trogontherii (Pohlig, 1885)

Figs. 3-4: Right Dp_4 from Liangjiapo, Linyi (V.6753), stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

3: Occlusal view.

4: Lingual view.

Figs. 5-6: Right M^3 from Pinglu (unnumbered), stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

5: Lingual view.

6: Occlusal view.

Scale bar = 10cm for figs. 1, 2, 5 and 6; and 5cm for figs. 3 and 4

Plate 6



Explanation of Plate 7

Mammuthus trogontherii (Pohlig, 1885)

Fig. 1: Left M_2 and M_3 planted on the mandible (Plate 8, figs. 1-3) from Xihoudu (V.2849), stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi.

Occlusal view.

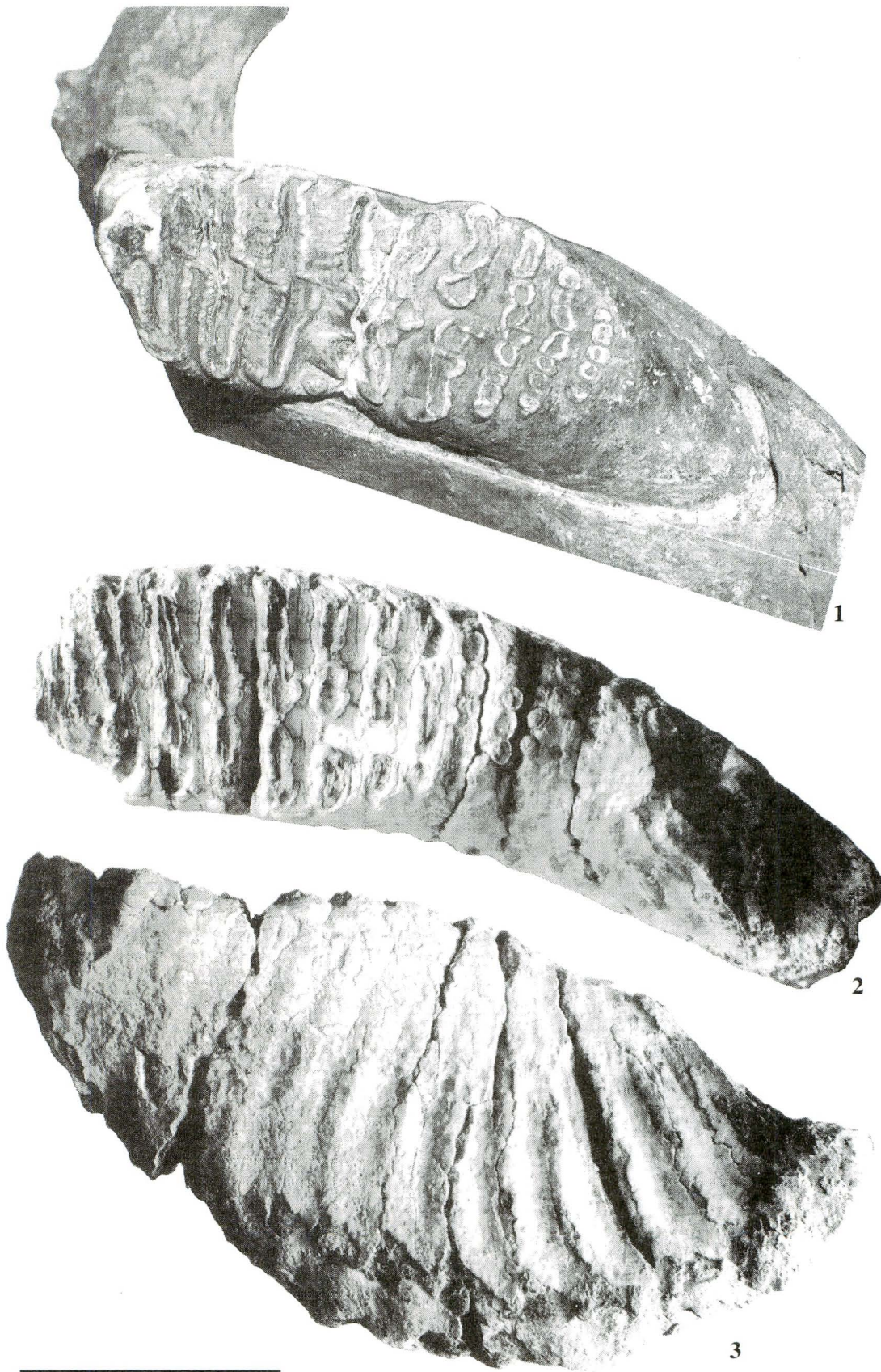
Figs. 2-3: Left M_3 from the Donggutuo site (T1-C 83-10-12), stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

2: Occlusal view.

3: Labial view.

Scale bar = 10cm

Plate 7



Explanation of Plate 8

Mammuthus trogontherii (Pohlig, 1885)

Figs. 1-3: Left mandible from Xihoudu (V.2849), stored in Shanxi Institute of Cultural Relics, Taiyuan, Shanxi.

- 1: Dorsal view.
- 2: Medial view.
- 3: Lateral view.

Mammuthus sp. indet.

Fig. 4: Right Dp^3 from Gaoya, Tianzhen (unnumbered), stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

Occlusal view.

Figs. 5-6: Right Dp^4 from Gaoya, Tianzhen (unnumbered), stored in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

- 5: Labial view.
- 6: Occlusal view.

Scale bar = 25cm for figs. 1-3, and 5cm for figs. 4-6

Plate 8

