

中国北方“第四纪(或亚代)”环境变化 与大哺乳动物演化¹⁾

邱占祥

(中国科学院古脊椎动物与古人类研究所 北京 100044)

摘要:地质年表 2004 的筹备和发表使关于“第四纪”概念、时限、阶元的讨论达到了高潮。目前的情势是,其下限下移至 ~2.6 Ma 几乎已成定局;其阶元究竟是“纪”还是“亚代”正在表决中(初步表决倾向于后者)。这样一来,“第四纪”就包括以海相地层为基础建立的晚上新世、更新世及全新世三大部分。中国北方“第四纪”大哺乳动物的研究已有很长的历史。现在应该根据新的情势重新审视其演化的阶段性及其与 ~2.6 Ma 以来环境变化之间的关系。对环境变化和大哺乳动物化石已有资料的分析表明:1) ~2.6 Ma 是北极冰盖大规模扩大,季风气候急剧加强,黄土开始在中国北方大面积沉积,哺乳动物群发生重大变化的时期。大量三趾马动物群特有的成员在此之前灭绝。2) ~2.6 至 1.3 Ma 是古老“第四纪”类型繁盛的时期。真马(*Equus*)和巨颞虎(*Megantereon*)从北美经过白令陆桥进入欧亚;一大批欧亚大陆起源的新属出现,如 *Eirictis*, *Meles*, *Crocota*, *Coelodonta*, *Eucladoceros*, *Elaphurus*, *Leptobos* 等。这一时期后期的气候,从黄土粒度曲线变化幅度普遍较小判断,应该相对比较稳定,较为温和。3) 1.3 ~ 0.13 Ma 为中华大角鹿(*Sinomegaceros*)异常繁盛的时期。一大批以周口店动物群为代表的典型中更新世的种类出现,如与狼接近的变异狼、中国硕鬣狗、意外巨颞虎、基什贝尔格犀等。这一时期之初有相当数量的东洋界分子越过秦岭进入中国北方的南部,如大熊猫、东方剑齿象、巨獾、毛冠鹿、鬃羚等。这一时期的气候起伏大,有明显逐渐变冷的趋势。从黄土粒度曲线看,至少有 3 次明显的冷期和一次较长的暖期(L15, L9, L2 和 S5)。因此,这一阶段是可以再分的,但这需要对哺乳动物化石和动物群的年代进行更为深入的研究。4) 0.13 ~ 0.011 Ma 出现大量现生种,如普氏野马、野驴、野猪、盘羊等;一些晚更新世特征的类型出现,如猛犸象、原始牛和具有奇特角枝的中华大角鹿等;在东北还出现了驼鹿化石。这一时期的气候波动不大,相对较温和。哺乳动物群所反映的特点应该是适应于寒冷气候的动物在较温和的气候条件下的辐射适应与新生现生种类的混合。5) 0.011 Ma ~ 现代,适应于寒冷气候的特殊类型,如猛犸象、披毛犀等灭绝。

上述 4 个哺乳动物演化阶段自下至上可以 NCMQ1 ~ 4 代表之。其中 NCMQ1 ~ 2 之间的界限与现在“第四纪”所包含的晚上新世—早更新世及早—中更新世的界限(1.8 Ma 和 0.78 Ma)并不一致。这种划分和北美及欧洲的哺乳动物分期都比较接近。北美的 Blancan 和 Irvingtonian 的分界约为 1.35 Ma;而欧洲维拉方期的顶界也在 1.1 ~ 1.4 Ma 之间。NCMQ3 和 NCMQ4 则与晚更新世及全新世相对应。

关键词:中国北方,“第四纪”,大哺乳动物,古环境

1) 国家自然科学基金项目(编号:40232023)资助。

中图法分类号:Q915.873 文献标识码:A 文章编号:1000-3118(2006)02-0109-24

QUATERNARY ENVIRONMENTAL CHANGES AND EVOLUTION OF LARGE MAMMALS IN NORTH CHINA

QIU Zhan-Xiang

(Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences Beijing 100044)

Abstract Preparation and publication of GTS 2004 led the discussion on the concept, time duration and rank of the "Quaternary" to a new height. Pending the final ratification, it seems almost certain that its lower boundary is to be lowered to ~2.6 Ma, but its rank as Period or Sub-Era remains to be decided. At any rate, the "Quaternary" will encompass 3 major units: the Late Pliocene, Pleistocene and Holocene, which are chiefly based on marine deposits. The "Quaternary" large mammals of North China has been extensively studied for a long time. Now it is advisable to review their evolution in light of the new perspective. Tentative analysis of the available paleoenvironmental data in conjunction with the evolutionary phases of the mammalian faunas shows the following: 1) ~2.6 Ma is certainly a critical period, at least in North Asia, when a number of events concurred. These include the great expansion of the Arctic ice sheet, the beginning of large-scaled loess deposition induced by intensification of monsoon system, and the extinction of large numbers of typical *Hipparion* fauna by ~2.6 Ma. 2) 2.6 ~ 1.3 Ma is a period flourished with archaic types of "Quaternary" large mammals. As immigrants from North America, *Equus* and *Megantereon* entered Eurasia at the beginning of the period. Large numbers of typical "Quaternary" genera appeared, like *Eirictis*, *Meles*, *Crocota*, *Coelodonta*, *Eucladoceros*, *Elaphurus*, *Leptobos*, etc. Climate of this period, especially its later half, was comparatively stable, rather mild in general, as shown in Ding et al.'s Chiloparts. 3) 1.3 ~ 0.13 Ma is characterized by particular development of *Sinomegaceros*. Typical Middle Pleistocene species as typified by ZKD fauna appeared, like *Canis variabilis*, *Pachycrocuta sinensis*, *Megantereon inexpectatus*, *Dicerorhinus kirchbergensis*, etc. A peculiar aspect is the invasion of Oriental elements into the south part of the North China, like *Ailuropoda*, *Stegodon orientalis*, *Megatapirus*, *Elaphodus*, *Capricornis*, etc., at the very beginning of this period. Climate of this period was highly variable, with at least 3 cold and one prolonged warm episodes (L15, L9, L2 and S5 in Chiloparts). Therefore, this period might be further subdivided when in-depth study is carried out in the future. 4) 0.13 ~ 0.011 Ma is characterized by a mixture of survived cold-adapted forms with living species. Climate of this period was probably mild. Such a climatic condition might have caused the adaptive radiation of the survived cold-adapted forms, as exemplified by the bizarre-antlered giant deer. 5) 0.011 Ma ~ Recent is equivalent to Holocene. Its mammalian fauna became modernized, with the final extinction of holdovers of the glacial period exemplified by mammoth and woolly rhinoceros.

We suggest that the above 4 phases be designated from earliest to latest as NCMQ1 ~ 4. The NCMQ1 - 2 boundary does not coincide with that of Plio-Pleistocene (1.8 Ma), neither with that of Early-Middle Pleistocene (0.78 Ma). However, such a subdivision is rather close to the subdivisions based on mammals currently adopted in North America and Europe. The Blancan-Irvingtonian boundary (in NALMA) lies at ~1.35 Ma. The upper boundary of the European Villafranchian lies also between 1.4 ~ 1.1 Ma.

Key words North China, Quaternary, large mammals, paleoenvironment

1 Status quo of the concept and definition of the Quaternary

After a century long confusion and debate over the term Quaternary, a real hope to reach an agreement on its lower boundary, time duration and status in Geologic Time Scale (GTS) is emerging finally. The last years witnessed an upsurging endeavor among stratigraphers of various specialities to re-define the concept of the Quaternary (Ogg, 2004; Pillans, 2004). The preparation and publication of a new GTS (2004) led by Gradstein, chair of the International Commission on Stratigraphy (ICS) of the International Union of Geologic Sciences (IUGS), might

have played a role of trigger for such an upsurge (Gradstein et al., 2004). Finally, a Quaternary Task Group (QTG) was organized jointly by ICS and INQUA, consisting of nine most authoritative specialists in this field headed by Gehling. The “single task” of QTG is “defining the Quaternary in a stratigraphic sense.” The final recommendations of the QTG are that: “1) The Quaternary be a formally defined and ratified geochronologic/chronostratigraphic subdivision of the Cenozoic Era/Erathem. 2) The base of the Quaternary be defined by the GSSP of the Gelasian Stage of the Pliocene. The Quaternary time span and associated geologic strata encompass the past ~2.6 million years of Earth’s history. 3) The Quaternary have a rank of either a Period or a Sub-Era”. In an ICS meeting held in Leuven, Belgium, in September, 2005, the QTG recommendations were debated and underwent voting by full voting members of ICS, and were passed by majority. In September 28th, 2005, the ICS submitted a report to the IUGS executive with the requests that the IUGS to ratify the recommendations.

Pending the final ratification, the Quaternary can now be viewed as a unit in GTS encompassing the last 2.6 myr, a recommendation adopted near-unanimously in QTG meeting. As a result, the Quaternary would encompass 5 discrete sub-units: Late Pliocene based on marine sediments, Early, Middle, Late Pleistocene and Holocene. It is advisable now to review the evolutionary events of the large mammals of North China Quaternary (thereafter NC and NCQ) in light of this new perspective, giving up the 1.8 Ma as a necessary boundary line.

2 Quaternary environmental changes in North China

Among the non-biologic environmental factors influencing evolution of the mammals, the major one is climate, which is a complexly coupled system resulted from interaction of the lithosphere, hydrosphere and atmosphere. These include the geographic position (especially latitudinal) and geomorphology of the habitat area, the size and configuration of the continent where the mammals live, the global sea-level fluctuation, and most importantly, the global forcing factors (precession, obliquity and eccentricity). As is shown in all currently available polar wandering curves (ex. gr., McElhinny, 1973), during the Quaternary time Asia was positioned already approximately as it is today, so that no meaningful latitudinal displacement would exist. The size and configuration of the Asian continent during the Quaternary time differed little from those of present day, with expansion/shrinkage of the eastern border area and emerging/sinking of Bering land-bridge caused mainly by global sea level fluctuation (Wang, 2004).

The emergence of the Bering land-bridge in the past had particularly important bearing on mammalian faunal composition through faunal exchanges between Asia and North America. It is well known that the global sea level changed dramatically during the Quaternary time. According to Haq et al. (1987), since the late Miocene there were 4 sea level rapid falls, magnitude of which exceeds all the previous ones except the first occurred in Permian. The last 3 falls occurred in the last 3 myr. In terms of sequence stratigraphy, they are: TB3.7 (2.9 ~ 2 Ma), TB3.8 (1.6 ~ 1.3 Ma) and TB3.9 (0.8 ~ 0.06 Ma). During the lowest stands of the sea level the Bering land-bridge would have allowed certain kinds of faunal exchanges (corridor, filter, etc.), causing changes in the faunas receiving successful immigrants.

As to the climate of the Quaternary, it is so different from those of other pre-Quaternary periods that Quaternary is often called the acme of the late Neogene “Icehouse”, which stepwise developed since the Mesozoic “Hothouse” via the Paleogene “Doubthouse” (Berggren and Prothero, 1992). Since the marine isotopic stages (MIS) are widely used as a major proxy indicator of global climate changes, the glaciation-based fourfold division of the Quaternary has been gradually replaced by the notion of frequently occurred warm-cold cycles of much shorter duration. For a long time in the past the MIS curves had been viewed as considerably monotonous, with their amplitude and duration little changed, in particular in the middle part. However, in

recent years more and more particular events were recognized in proxy records in continental deposits. Mainly based on loess deposits, Kukla and Cilek (1996) subdivided the Quaternary MIS into 10 megacycles, each starting with exceptionally thick and/or coarse sandy loess. In addition to the last 4 megacycles (MIS 1 ~ 24), which correspond to the 4 traditional glacial-interglacial cycles, 6 megacycles were erected based on the loess layers in Luochuan section: L13 (MIS 34), L15 (MIS 40), WL1 (MIS 54), WL2 (MIS 66), WL3 (MIS 86), and WL4 (MIS 100). The MIS 96, 98, and 100 are rather prominent in comparison with the MIS above them, as is presented in Kukla and Cilek paper's fig. 3. Kukla and Cilek also stressed that the earliest 3 MIS maxima "are associated with the appearance of abundant ice-rafted detritus in the North Atlantic deep sea sediments."

Recently, Ding et al. (2002) published a new interpretation of the Quaternary climate changes based on high-resolution grain size records of 5 most representative loess sections of NC Loess Plateau. The authors created the term "Chiloparts" to designate the "Chinese loess particle time scale", and correlated the synthesized Chiloparts curve based on 5 loess sections with the MIS data (based on ODP 677) in great detail. In the Chiloparts (see Figs. 1 ~ 2) it is clearly seen that there are only 4 particularly high peaks: L2 (MIS 6, 0.128 ~ 0.19 Ma), L9 (MIS 22 ~ 24, 0.865 ~ 0.943 Ma), L15 (MIS 38, 1.24 ~ 1.263 Ma) and L33 (MIS 101 ~ 103, 2.547 ~ 2.59 Ma). Ding et al. noticed the discrepancy between the Chiloparts and the MIS curves: "the extreme climatic conditions marked by units L9, L15 and L33 are not so prominent in the $\delta^{18}\text{O}$ record." However, these are considered as "a product of extreme regional events."

Recent study of South China Sea (ODP Leg 184) led by Wang Pinxian since 1999 has tremendously enhanced our understanding of the Neogene climate changes of the Western Pacific immediately bordered the Asian continent. As for the Quaternary climate, some of the important results are as follows. Based on the 6 drilling holes (ODP 1143 ~ 1148), it is concluded that the formation of the Arctic glaciation should occurred around 3.5 ~ 2.5 Ma and a significant expansion at about 0.9 Ma when the benthic $\delta^{18}\text{O}$ became prominently heavier (Wang et al., 2003). In another paper (Tian et al., 2002) it is showed that 3 major intervals (3.6 ~ 2.7, 2.7 ~ 2.1 and 1.5 ~ 0.25 Ma) representing 3 glacial cycles can easily be detected. Each interval begins with a rapid negative shift in Atlantic-Pacific difference of benthic $\Delta\delta^{18}\text{O}$ and then gradually increased. The middle one (2.7 ~ 2.1 Ma) has the most dramatic shift between 2.7 ~ 2.55 Ma among the three. This should be the most important stage in Arctic ice sheet occurred at the base of the Quaternary. Another interesting fact pointed out in Tian et al.'s paper is that 2.9 Ma seems to be a threshold for the sedimentation rate in ODP Site 1143. Before this time the average rate is ~39.5 m/myr, while after this time the rate jumped to ~65.4 m/myr, with a maximum amplitude as large as 200 m/myr.

Based on the above climatic data deduced from marine (especially from the South China Sea) and loess deposits, the NC Quaternary (thereafter NCQ) climate as exemplified by the Loess Plateau can be summarized as follows.

1) The formation of Northern Hemisphere glaciation was a stepwise process taking place probably from late Miocene. However, clearer sign of its appearance is to be dated as from 2.9 ~ 2.5 Ma, slightly prior to, and/or across the Quaternary lower boundary, as evidenced by the TB3.7 sea-level fall, the appearance of large-scale ice-rafted debris in the Sub-Arctic Pacific, the MIS 96, 98 and 100 in marine isotopic records, the L33 coarsening in Chiloparts, and the data obtained from benthic $\delta^{18}\text{O}$ in South China Sea. As demonstrated by the beginning of large-scale loess deposits, a product of severe winter monsoon, at 2.59 Ma (L33), the effect of glaciation on climate in the middle latitude portion of the continent in general, NC in particular, may slightly lag behind.

2) In the time span from L33 to L15 (2.59 ~ 1.25 Ma), especially in its upper half, from

L24 to L16 (1.75 ~ 1.3 Ma), the amplitude of climatic changes is rather small, as demonstrated by the rather monotonous curve in the Chiloparts.

3) In the later half of the Early Pleistocene 2 prominent climatic deterioration events might have occurred: L15 (1.25 Ma) and L9 (0.943 ~ 0.865 Ma). The later half of the Middle Pleistocene witnessed another prominent deterioration event: L2 (0.19 ~ 0.13 Ma).

4) S5-1 ~ S5-3 (0.62 ~ 0.48 Ma) might be a prolonged time period characterized by mild climate.

3 Quaternary large mammals in North China

3.1 Selected major representative mammalian faunas

During the Quaternary, as the climate rapidly changed, organism changed as well. The large mammal faunas of NCQ showed 4 evolutionary phases, characterized each by its own peculiar features (*vide infra*): 1) 2.6 ~ 1.3 Ma, corresponding to Late Pliocene (Gelasian) ~ early Early Pleistocene; 2) 1.3 ~ 0.13 Ma, corresponding to late Early Pleistocene ~ Middle Pleistocene, with at least 3 major deterioration events (1.25, 0.9, 0.19 ~ 0.13 Ma) and one prolonged warm period (0.62 ~ 0.48 Ma); 3) 0.13 ~ 0.011 Ma, corresponding to Late Pleistocene; and 4) 0.011 Ma ~ Present, corresponding to Holocene. For convenience's sake, they can be provisionally called as NCMQ (North China Mammal Quaternary) 1 ~ 4 from bottom to top, denoting the subdivision of Quaternary based on evolutionary stages of North China large mammals. The following faunas are presented in chronologic order with the principal original references and current status of age determination (Fig. 1).

3.1.1 NCMQ1

Longdan fauna (Dongxiang, Gansu) is the earliest Quaternary mammalian fauna with abundant fossils and paleomagnetic dating so far known in NC. It was discovered in 2 loess layers in basal part of "Wucheng loess". Altogether 31 species were monographically described by Qiu et al. (2004). Later collection added 4 new forms, belonging to *Sus*, *Ursus* and *Postschizotherium*, undescribed yet, and *Castor anderssoni* (Wang, 2005). The fauna has been paleomagnetically dated as 2.58 ~ 2.25 Ma.

Zhoukoudian (ZKD, = Choukoutien) Loc. 18 fauna (Beijing), one of the classical NCQ faunas, was first described by Teilhard de Chardin (1940), consisting of 27 mammalian forms. Based on micromammals, Zheng and Zhang (2001) considered it older than 2 Ma.

Nihewan fauna (s. s.) (Yangyuan, Hebei), the largest and most classical, and the earliest described NCQ fauna (Teilhard de Chardin and Piveteau, 1930). The original description contained 42 forms with 18 of them identified to species. According to Qiu (2000), the Nihewan fauna is very close to that of Senèze (France), which is paleontologically dated as ~ 1.9 Ma. However, based on the presence of *Mammuthus trogontherii* (recent discovery from Majuangou near Nihewan), Wei (2004) regarded its age probably around 1.6 Ma.

Fauna of Xihoudu (= Hsihoudu) Paleolithic Site (Ruicheng, Shanxi) was described by Jia and Wang (1978), consisting of 21 forms. Its age was first suggested roughly as about that of Nihewan. Recently, based on his referral of the Xihoudu elephantine material to *Mammuthus meridionalis*, Wei (2004) came to the conclusion that Xihoudu was older than Nihewan, therefore, 1.8 ~ 2 Ma. On the other hand, Zhu et al. (2002), having conducted paleomagnetic work at this site, suggested a much younger age for it: ~ 1.3 Ma.

Yangguo fauna (Lantian area, Shaanxi) is a composite one, collected from 4 localities (Jiulangou, Liujiaping, but mainly from Xichawan and Laochihe), consisting of 21 forms. It was originally described by Ji (1975). The fossils came from the basal part of the "reddish clay", mainly sandy calcareous soil. Ji placed this fauna in early Quaternary, between Nihewan and ZKD Loc. 18 in age. Qiu et al. (2004) pointed out that the material referred by Ji to *Axis*

cf. *A. rugosus*, *Axis* cf. *A. shansius* could belong to *Nipponicervus elegans*, and *Leptobos ampli-frontalis* and *L. laochihensis* to *Leptobos brevicornis*.

Yue and Xue (1996), based on correlation of Xichawan section with that of Lantian, placed the Yangguo fossils-bearing layers to L12 – L13, thus made the Yangguo fauna later in age, at about 0.9 ~ 1 Ma. However, this age assignment seems not in accordance with the archaic feature of the fauna. The Yangguo fauna is very close to those of Nihewan and Xihoudu. If the upper sandy loess of the Xichawan section is interpreted as L15, not L9 as Yue and Xue (1996) did, then the fossil-bearing layers would be correlated with L19 – L20, which according to Ding et al. (2002) should be around 1.4 Ma. This would be a better age estimation, although the fauna tends to show even older age.

3.1.2 NCMQ2

Fauna of Gongwangling *Homo erectus* Site (Lantian, Shaanxi) was systematically described by Hu and Qi (1978), consisting of 41 mammalian forms. An et al. (1990) made a careful correlation of the Gongwangling loess section with that of Luochuan and concluded that the Gongwangling fossils-bearing sandy loess layer was correlatable with L15 in Luochuan section and its age should be 1.15 Ma. According to currently refined Chiloparts (Ding et al., 2002), L15 is correlated with MIS 38, at ~ 1.25 Ma. However, from the viewpoint of paleontology and paleoclimatology, it is more reasonable to place it just prior to the L15 deterioration event, i. e., slightly older than 1.25 Ma, probably 1.3 Ma (*vide infra*).

Fauna of Kehe Paleolithic Site (Ruicheng, Shanxi) was briefly described by Jia et al. (1962), consisting of only 10 mammalian forms. Some of these forms were later revised by other authors. Chow and Zhai (1962) established a new species, *Stegodon chiai*, based on material from Kehe referred to *Stegodon zdanskyi*. Qiu et al. (1987) noticed that among the horse teeth from Kehe there were at least 2 teeth belonging to *Hipparion* (*Proboscideipparion*). The age of the Kehe Paleolithic Site is now generally considered ~ 1 Ma (Qiu, 1987).

Fauna of Chenjiawo (= Chen-chia-ou) *Homo erectus* Site (Lantian, Shaanxi) was described by Chow (1964) and Chow and Li (1965), consisting of only 15 mammalian forms. Its age is definitely of Middle Pleistocene. According to An et al. (1990), the fossil-bearing layer of Chenjiawo was correlatable with S6 of the Louchuan loess section, which was dated as 0.65 Ma. According to Ding et al.'s Chiloparts (2002), the age of S6 is 0.68 ~ 0.71 Ma.

Fauna of ZKD Beijing (= Peking) Man Site (Loc. 1) is the most famous Middle Pleistocene mammalian fauna in China. It was described by a large number of authors in the first half of the last century. Most important monographs were published by Zdansky (1928), Young (1932), Pei (1934) and Teilhard de Chardin and Pei (1941). Opinion as to its age varies considerably, although majority of the age estimations are confined to the lower part of Middle Pleistocene. The current tendency is to place the main fossiliferous layers 2 ~ 12 into the time span of 0.69 ~ 0.42 Ma (Gaboardi et al., 2005).

Fauna of Jinniushan Paleolithic Site (layer 3 ~ 6 of Cave A) (Yingkou, Liaoning) was systematically described by Zheng and Han (in Zhang, 1993), consisting of 52 mammalian forms (28 small mammals). Zheng and Han correlated layers 5 ~ 6 of the Jinniushan cave A with layers 4 ~ 5 of ZKD Loc. 1, corresponding either to MIS 13 (Gaboardi et al., 2005), thus ~ 0.5 Ma (Ding et al., 2002), or MIS 9 (Xu et al., 1997), thus ~ 0.35 Ma (Ding et al., 2002).

Fauna of Miaohoushan Formation (layer 4 ~ 6) (Benxi, Liaoning) was preliminarily described by staff members of the Museum of Liaoning Province and Museum of Benxi City (1986), listed as belonging to 21 mammalian forms. Estimated age using various isotopic dating methods for layer 4 varied from 0.4 ~ 0.34 Ma, and for layer 6 to 0.14 Ma.

3.1.3 NCMQ3

Sjara-osso-gol Fauna (Ordos [formerly Dongsheng], Nei Mongol) was described by Boule

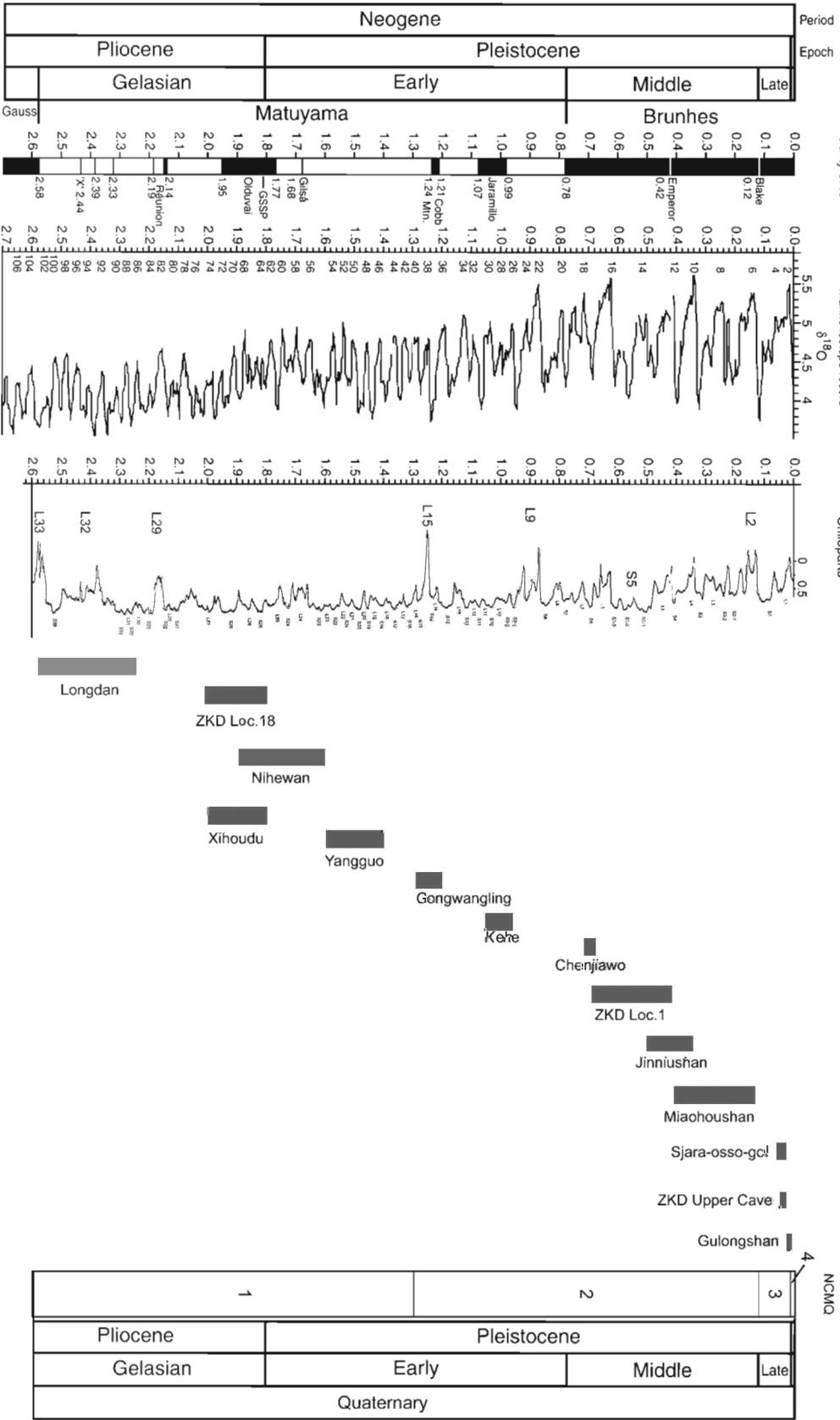


Fig. 1 Temporal distribution of selected major representative mammalian faunas of NCQ (Neogene Climatic Mammal Quaternary) are excerpted from GTS 2004 (Gradstein et al., 2004); synthesized Chiloparts are re-drawn from Ding et al. (2002, fig. 12); and the NCMQ subdivisions are shown at the right side

and Teilhard de Chardin (in Boule et al., 1928), consisting of 33 mammalian forms. Its age is about 0.05 ~ 0.037 Ma according to Qi (in Wu et al., 1989).

Fauna of ZKD Upper Cave *Homo sapiens* Site was partly described by Pei (1940), consisting of 47 mammalian forms. Its age was estimated as 0.027 ~ 0.034 Ma using C¹⁴ dating method according to Qi (in Wu et al., 1989).

Gulongshan fauna (Dalian, Liaoning) contains altogether 57 mammal forms, but the fauna was only partially studied and published (Zhou et al., 1990). The age of the main fossiliferous layer was determined as 0.017 Ma using C¹⁴ dating method.

There are still a large number of Late Pleistocene localities with large mammals, like Xujiayao, Dingcun, Guxiangtun, Yushu, etc. Although their Late Pleistocene affinity is beyond doubt, further systematic study of these faunas and detailed geologic survey of the localities are needed.

The temporal distribution and approximate time duration of the above listed fossil bearing layers are roughly shown in Fig. 1.

3.2 Systematic review of the major representative NCQ large mammals

3.2.1 Carnivora (Fig. 2)

3.2.1.1 Canidae

The canid genera so far found in NCQ are: *Eucyon*, *Canis*, *Nyctereutes*, *Vulpes*, *Sinicuon* and *Cuon*.

Available paleontologic records show clearly that progenitors of the Eurasian canids (s. s.) were immigrants from North America through one or more migration waves via Bering land-bridge. The earliest record is *Canis cipio* from Spain, allegedly of late Turolian (MN 12) in age (Crusafont-Pairo, 1950). However, the major migration event occurred evidently around the Mio-Pliocene boundary (TB3.3, ~5.5 Ma). By the Middle Pliocene *Eucyon*, *Canis*, *Nyctereutes* and *Vulpes* existed already in South Europe and North Asia, as demonstrated by remains from Spain (Brisighella, Venta del Moro), France (Perpignan), Ukraine (Odessa Catacombs), China (Yushe, Lingtai), Turkey (Calta), and Mongolia (Khirgis Nur). Only *Sinicuon* and *Cuon* were confined to Quaternary. The last 2 specialized genera probably originated from some early form of *Canis* already inhabited Eurasia.

At the beginning of Quaternary the canids rapidly flourished and became dominant in the carnivore guild in NC. The Longdan fauna contains abundant fossils of 3 species of wolf-sized *Canis* (*C. teilhardi*, *C. longdanensis* and *C. brevicephalus*), *Vulpes* and *Sinicuon*, but without *Nyctereutes* (Qiu et al. 2004). The reason for the absence of *Nyctereutes* in Longdan fauna is not clear for the moment. Similarly abundant fossils of canids were found also in Nihewan, with slightly different species composition (*Eucyon minor*, *Canis chihliensis*, *Canis parmidens*, *Nyctereutes sinensis*, and *Vulpes* sp.).

Primitive forms of true wolves first appeared in Gongwangling (base of NCMQ2), where *Canis variabilis*, a small form close to, but more primitive than *Canis lupus* (see Qiu et al., 2004, p. 49, 173) was recorded (Hu and Qi, 1978). Fossils of *Canis variabilis* are particularly rich in ZKD Loc. 1 (Pei, 1934). It might be well established and widespread in Middle Pleistocene of NC, from Qinghai (Gonghe) to Northeast China (Miaohoushan). The earliest record of the true wolf, *Canis lupus*, is from the Xujiayao Paleolithic Site (around Middle-Late Pleistocene boundary). In the later half of NCMQ3 (Late Pleistocene) and NCMQ4 (Holocene) the wolf became widespread, especially in the Northeast of China (Sjara-osso-gol, Gulongshan, etc.).

The first fossils of the genus *Nyctereutes*, *N. sinensis*, were recorded in Middle Pliocene in China (Yushe). The latest occurrence of undoubted material of it is from the Nihewan fauna. It is a pity that no raccon-dog fossils were found from Longdan and Gongwangling. However, as

pointed by Tedford and Qiu (1991), the raccon-dog fossils of ZKD Loc. 1, originally identified as *Nyctereutes sinensis*, might be in reality a slightly large-sized form of the living form, *Nyctereutes procyonoides*. The true *Nyctereutes procyonoides* first appeared in the later half of NCMQ3 (ZKD Upper Cave).

Vulpes chikushanensis existed in the time span from the base of NCMQ1 (Longdan) to the early Middle Pleistocene (ZKD Loc. 6). During the Middle Pleistocene *Vulpes* apparently experienced a rapid development. Probably, the 2 living species, *Vulpes corsac* and *Vulpes vulpes* did exist already in Middle Pleistocene, as evidenced by the rich material from ZKD identified by Pei (1934) as *Vulpes* cf. *V. corsac* and *Vulpes* cf. *V. vulpes*. From then on the 2 living species became frequently found in North and Northeast China.

Distribution of *Sinicuon dubius* is probably confined to NCMQ1 (Longdan, ZKD Loc. 18, Haiyan). The living dhole, *Cuon alpinus*, first appeared at the very beginning of Middle Pleistocene (Chenjiawo). The material found from ZKD, identified by Pei (1934) as *Cuon* cf. *C. alpinus* should attributed to the living species *Cuon alpinus*, although slightly larger in size and possessing some archaic features (Pei, 1987).

3.2.1.2 Ursidae

The NCQ ursids comprise only 2 genera: *Ursus* (s. l.) and *Ailuropoda*, both of which are Eurasian in origin.

Primitive and small sized forms, *U. minutus* etc., were found from pre-Quaternary Pliocene in Europe (Roussillon, Baron-Kopécz) and Asia (unpublished material from Yushe). During NCMQ1 in NC most of the bear fossils were provisionally identified as belonging to *Ursus etruscus* (ZKD Loc. 18, Nihewan), a form widespread in Middle Villafranchian in Europe. In fact, all these fossils are smaller in size and more primitive than the typical European *Ursus etruscus*, but closer to *Ursus minimus*. The 2 mandibles found from Yangguo, identified by Ji (1975) as *Ursus* cf. *U. kokeni*, may belong to 2 species: V 4568. 1 (PI I 7a) to *Ursus minimus*, which might be an ancestral form of *U. arctos*, and V 4568. 2 (PI I 7b) to a primitive form of *Ursus thibetanus*. The bear fossils from Gongwangling identified as *Ursus* cf. *U. etruscus* by Hu and Qi (1978), judging from its small size, may also belong to *Ursus thibetanus*. Therefore, in NCMQ1 both lineages (brown and black bears) were present. The brown bear lineage was represented by a primitive form, close to *Ursus minimus*, while the black bear lineage was represented by a primitive form of *Ursus thibetanus*. At the base of NCMQ2 the true black bear appeared (Gongwangling). From Middle Pleistocene on, the brown and black bears existed contemporarily and persist until today. At Middle Pleistocene the cave bear, *Ursus spelaeus*, could also appeared (ZKD). Its last occurrence in NC is recorded from late NCMQ3 (ZKD Upper Cave).

The panda, *Ailuropoda melanoleuca*, an element of the *Ailuropoda-Stegodon* fauna of the Oriental Realm, invaded NC only once, at the very beginning of NCMQ2 (Gonwangling).

3.2.1.3 Mustelidae

The mustelids living now in NC are numerous. They belong to 7 genera: *Martes*, *Gulo*, *Mustela*, *Vormela*, *Meles*, *Arctonyx* and *Lutra*. In NCQ all of them were recorded. In addition, there existed an extinct genus, *Eirictis*.

Eirictis, a newly established genus, is very close to the European Villafranchian *Pannonictis* in morphology, but its distribution in NC, so far as is known, is confined to early NCMQ1 (Longdan, Fanchang and Nihewan).

There are 3 living *Martes* species in NC: *M. flavigula*, a form preferably living in forest habitat; *M. foina*, living mainly in maintain areas of dry and cold climate; and *M. zibellina*, living mainly in pine forests. *Martes* had apparently a long history in Asia. Large-sized martines were considerably diversified and rather abundantly represented in fossils in pre-Quaternary Mio-Pliocene deposits (Baode, Yushe etc.). However, NCQ fossils of *Martes* were rare and

poorly studied. There was only one record from early NCMQ1 (ZKD Loc. 18), a badly preserved skull of *Martes* sp. (Teilhard de Chardin, 1940). Judging from its small size and the convergent auditory bullae, the skull from ZKD Loc. 18 might be an ancestral form of *Martes foina*. Another record was a lower jaw of *Martes* sp. from Middle Pleistocene (ZKD Loc. 13, Teilhard de Chardin and Pei, 1941). This might also belong to *Martes foina*.

On the other hand, the meline fossils are much more abundant in both pre-Quaternary and Quaternary deposits in NC. A large number of species belonging to *Parataxidea*, *Melodon* and *Arctomeles* were described from Late Miocene and Pliocene deposits. However, *Meles* did not appear until probably Middle Pliocene (ZKD Loc. 12). From early NCMQ1, *M. teilhardi* (Longdan) and *M. chiai* (ZKD Loc. 18, Nihewan, Haiyan) were reported. The affinity of the Gongwangling badger, identified as *M. cf. M. leucurus*, is so far uncertain. In size it is similar to *Arctomeles*, but without the specialized feature of the latter. From the base of Middle Pleistocene on, fossils of *Meles meles* were often found (Chenjiawo, ZKD Loc. 1, Sjara-osso-gol, etc.).

Mustela is the most diversified genus among living mustelids in NC, represented at least by 7 species with a large number of subspecies. However, its fossil records are rare and remained poorly studied. Its earliest fossils were reported from ZKD Loc. 18. From Middle Pleistocene (ZKD Loc. 1) on, fossils referable to this genus were often found.

Fossils of *Gulo* and *Lutra* were only sporadically found in NC. A fossil species, *Gulo schlosseri*, was found in ZKD Loc. 1, whereas good material of the true glutton, *Gulo gulo*, was found in Late Pleistocene in Northeast China (Xu and Wei, 1987). A fossil beaver species, *Lutra licenti*, was also recorded from Nihewan.

3.2.1.4 Hyaenidae

The hyaenids had a very prosperous development during the pre-Quaternary Neogene in both Eurasia and Africa, represented by numerous genera and abundant fossils. From Pliocene they sharply declined, and in NCQ there were only 3 genera left: *Chasmaporthetes*, *Pachycrocuta* and *Crocuta*.

Chasmaporthetes is a particular group of hyaenids specialized in the direction of cheetah in limb proportion. It first appeared in the beginning of Pliocene (Yushe), and persisted into the early NCMQ1 (Longdan, Nihewan), evolved into a new species, *C. progressus*, and then disappeared completely.

Pachycrocuta is the most successful and dominant hyaenids living in NCQ. Its evolution seems rather gradual, from the Pliocene *P. pyrenaica* (Yushe, Qiu, 1987) to NCMQ1 *P. licenti* (Longdan, Nihewan, Yangguo), then to NCMQ2 *P. sinensis* (Gongwangling, ZKD Loc. 1, Miaohoushan, etc.).

Crocuta comprises 2 species in NCQ. The primitive one, *C. honanensis*, is confined in early NCMQ1 (Longdan, Nihewan), whereas the earliest record of the most specialized *C. ultima* was reported from the top of Middle Pleistocene (Miaohoushan, Layer 6). In NCMQ3 *C. ultima* became rather widespread in NC (ZKD Upper Cave, Sjara-osso-gol, etc.). By the end NCMQ3 *C. ultima* became extinct completely.

3.2.1.5 Felidae

Among the saber-toothed cats only 2 genera, *Homotherium* and *Megantereon*, lived in NCQ. Fossils of primitive *Homotherium* were found in Licent's old collection, from Middle Pliocene (unpublished material from Yushe). In NCMQ1 the main form is *H. crenatidens* (Longdan, Nihewan, Fanchang). A more advanced representative of this genus is *H. ultimum*, which was found in ZKD Loc. 1, 9 & 13. The last representative of *Homotherium* is the fossils from Jinniushan described by Zheng and Han (in Zhang, 1993) as *H. cuii*. *Megantereon* may be a Quaternary form in Eurasia. No ancestral forms were ever found in Eurasian pre-Quaternary deposits. However, in North America fossils of primitive *Megantereon*, *M. hesperus*, were discovered in Middle Blancan deposits (Hagermann, ~3.5 Ma, Bjork, 1970). Therefore, *Megantereon* may

be an immigrant from North America, probably together with the true horse, *Equus*. In NCQ the species is *M. nihowanensis* (Longdan, Nihewan, etc.). The specimen of *Megantereon* from Gongwangling was erected as a new species, *M. lantianensis*. As pointed out by Qiu et al. (2004), it might belong to the same species as of ZKD Loc. 1, *M. inexpectatus*. At any rate, both *Megantereon* and *Homotherium* did not survive Middle Pleistocene in NC.

The quasi-saber-toothed cats, *Metailurus*, a form widespread in pre-Quaternary Neogene of North Asia, has never been found in Quaternary. It became extinct just prior to the Quaternary.

The history of *Lynx* can be traced back to pre-Quaternary Pliocene in NC. A large-sized species, *L. shansius*, lived from Middle Pliocene (unpublished material from Yushe) to NCMQ1 (Longdan, Nihewan, Yangguo, base of Wucheng Loess, etc.). It is rather unexpected that during NCMQ2 records of *Lynx* fossils are extremely rare. In NCMQ3 fossils of true lynx, *Lynx lynx*, were already frequently found (ZKD Upper Cave, Gulongshan).

Evolutionary history of the living small-sized cats is so far poorly understood. This rendered their identification at specific level rather difficult. Taken as a whole, the genus *Felis* existed since Middle Pliocene in NC (unpublished material from Yushe). No evident evolutionary events can be clearly distinguished in this genus.

Evolutionary history of the large-sized tigers, *Panthera*, is rather complicated. Some fragmentary *Panthera* material (undescribed) was found from Middle Pliocene deposits in Yushe. *Panthera palaeosinensis* has been considered the ancestral form of the living *Panthera tigris* (Hemmer, 1967). Its type was found from Henan (Andersson, Lok. 39, Mianchi). Judging from its associated forms (*Proboscideipparion*, *Equus* and *Paracamelus*), the age of *P. palaeosinensis* should be assigned to NCMQ1. This form was also found in other NCMQ1 deposits (Longdan, Yangguo). The tiger from Gongwangling belonged already to *Panthera tigris* (originally identified as *Panthera* cf. *P. tigris*), implying that this living species first appeared at 1.3 Ma. In Middle Pleistocene *P. tigris* and a large-sized *P. youngi* became more often found (Chenjiawo, ZKD, Miaohoushan, etc.), whereas in NCMQ3 *P. tigris* became widespread (Sjarosso-gol, Loufangzi, Rouyuan, etc.). *Panthera pardus* may have the same long history as *P. tigris*. Its first reliable fossils were also found from Gongwangling. In Middle and Late Pleistocene it is well represented (ZKD, etc.).

Cheetah (*Acinonyx jubatus*) is now living only in Africa, Middle Asia and India, but its fossil relatives were widely distributed in almost entire Eurasia. *Sivapanthera* has been considered its progenitor. The earliest fossils of *Sivapanthera* were found from Middle Pliocene (unpublished material from Yushe). The earliest NCQ species is *S. linxiaensis*, found from Longdan. The other NCMQ1 species is *S. pleistocaenica*, type specimen of which came from loess deposit in Yuanqu, Shanxi. The latest appearance of this species was recorded in Gongwangling. According to Qiu et al. (2004), the lower jaw from Nihewan, originally identified as *S. pleistocaenica*, might belong to an ancestral form of the living genus *Acinonyx*. This would mean that *Acinonyx* appeared rather early in NCQ, in late NCMQ1 (~1.8 Ma). Fossils of true cheetah, *A. jubatus*, were found in NCMQ3 (ZKD Upper Cave, localities in Northeast China). *Acinonyx jubatus* apparently did not survive Pleistocene in NC.

The temporal ranges of the above listed carnivores are roughly shown in Fig. 2.

3.2.2 Proboscidea (Fig. 3)

In NCQ only 3 genera were found: *Stegodon*, *Mammuthus* and *Elephas* (*Palaeoloxodon*).

Within the genus *Stegodon* there might be 2 lineages: the Paleoarctic one, consisting of primitive Pliocene forms like *S. zdanskyi*, etc., and advanced Quaternary form, *S. chiai*; and the Oriental one, consisting mainly of *S. orientalis*. The record of the Paleoarctic forms of *Stegodon* in NCQ is very poor. An incomplete molar of *Stegodon* sp. was found from Xihoudu. *Stegodon chiai* was established by Chow and Zhai (1962) based on the material from Kehe originally identified by Jia et al. (1962) as *Stegodon zdanskyi*. *Stegodon chiai* is the last and most advanced

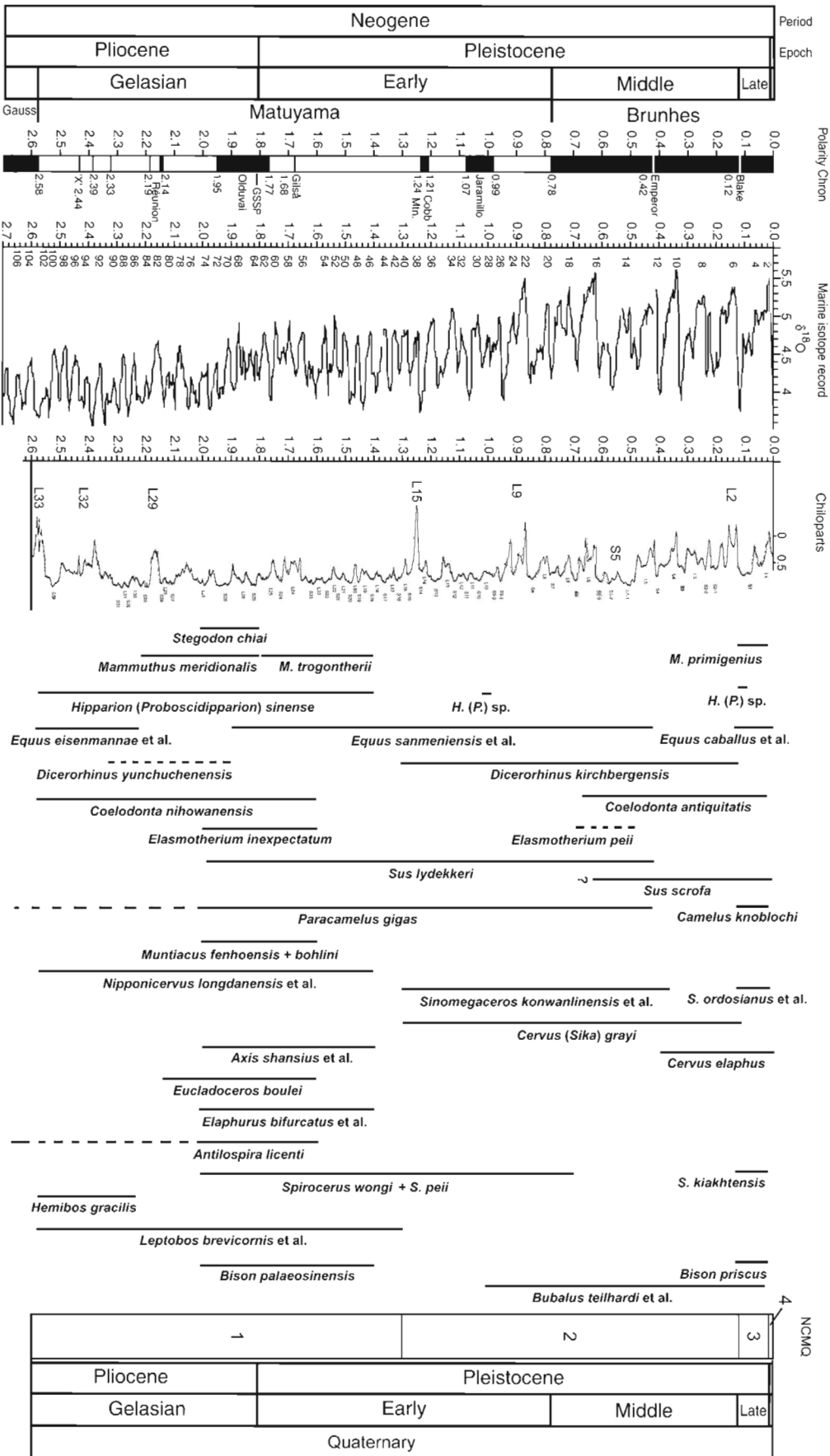


Fig. 3 Temporal ranges of selected NCQ proboscideans, perissodactyls and artiodactyls Time Scale, Polarity Chron, and Marine isotopic record, Chlopartis, and NCMQ subdivisions are as in Fig. 1

representative of this Palearctic lineage in NC.

As invader from the Oriental Realm, *Stegodon orientalis* occurred occasionally in NCQ as well. Some fossils of this species were discovered in early NCMQ2 (Gongwangling, Kehe?, Middle Pleistocene localities in Laochihe area). No remains of *Stegodon* have ever been found in Northeast China.

In current taxonomic practice (McKenna and Bell, 1997), the Elephantinae comprise only 2 genera: *Mammuthus* and *Elephas*. In this case *Palaeoloxodon* is considered a subgenus of *Elephas*.

Based on a systematic review of the Chinese *Mammuthus*, Wei (2004) transferred the Youhe *Elephas youheensis* (3.1 ~ 2.6 Ma) to *Mammuthus rumanus*. This would extend the history of the genus back to Middle Pliocene. In the same article Wei also transferred a series of variously named elephant teeth of NCMQ1 (Xihoudu, Houhecun, etc.) into *M. meridionalis*. Thus, in early NCMQ1 there was only one mammoth species, *M. meridionalis*. In late NCMQ1 the mammoth species was mainly *M. trogontherii*. In northeast Siberia the transition from *M. trogontherii* to *M. primigenius* occurred at the beginning of Middle Pleistocene (Wei, 2004, p. 97). However, the mammoth fossils of Middle Pleistocene in China were scarcely reported. In NCMQ3 fossils of *M. primigenius* became extremely rich in north part of Eurasia, between 40° ~ 70°N. In China its distribution is mainly in Northeast China, with its south boundary extended to 38°N (Chow, 1978).

A systematic review of the fossils referred to *Elephas* (*Palaeoloxodon*) is badly needed. What can be said now is that fossils which might belong to this subgenus were mainly found in Middle Pleistocene in NC. It might persist into NCMQ3 (Sjara-osso-gol) as well.

3.2.3 Perissodactyla (Fig. 3)

3.2.3.1 Equidae

The most magnificent and well known paleozoogeographic events in Neogene are the migration waves of 3 types of North American horses into Eurasia via Bering land-bridge. For most of vertebrate paleontologists it has long been considered well established that the monodactyl true horse, *Equus*, immigrated into Eurasia at ~ 2.6 Ma (Azzaroli, 1992), now the lower boundary of Quaternary. However, based on fossil records from Khazakhstan (Lebiazhe), some specialists of former USSR insisted on earlier date of this immigration, at about 3.5 Ma (e. g., Vislobokova et al., 2003). At any rate, it is commonly accepted that more successful and large-scaled migration event of *Equus* should occur around 2.6 Ma. The earliest horse appeared in NCQ is *Equus eisenmannae* (Longdan), the largest horse so far found in Eurasia. This is in accordance with the extremely large size of the earliest horses found in other localities, like *Equus livenzovensis* from Southern Russia. The most common horse living in NCMQ1-2 of NC, however, is *Equus sanmeniensis*, a considerably large horse with mixture of both primitive and advanced characters. During the early NCMQ1 some other horses also existed: *E. teilhardi*, *E. qingyangensis*, and *E. wangi* (Deng and Xue, 1999). The NCMQ3 witnessed another rapid diversification of horses: *E. caballus*, *E. przewalskii* and *E. hemionus*. It is also interesting to note that in Northeast China a special horse species with more robust metapodials was recognized in NCMQ3, *Equus dalianensis* (Zhou et al., 1985).

Of the hipparionines only one species evolved from Pliocene to Quaternary: *Hipparion* (*Proboscidipparion*) *sinense*. Fossils of this species were rather widespread in the central part of NC, mainly in NCMQ1 deposits (Longdan, base of Wucheng loess section, Xihoudu, Yangguo). It is interesting to note that some of the horse teeth from Kehe and Loufangzi referred to *Equus* sp. should be transferred to *Hipparion* (*Proboscidipparion*). Loufangzhi fauna is dated as ~ 0.1 Ma. If this can prove tenable, this would be the latest appearance of the hipparionines in the world.

3.2.3.2 Rhinocerotidae

In NCQ lived altogether 4 genera of Rhinocerotidae: *Dicerorhinus*, *Coelodonta*, *Rhinoceros*, and *Elasmotherium*.

There is no agreement as to whether the generic name of the living Asian *Dicerorhinus* could be applied to the large-sized Neogene tandem-horned rhinoceroses. Just for the sake of simplicity, the generic name *Dicerorhinus* is retained here. The earliest fossil record of this genus in NCQ is *Dicerorhinus yunchuchenensis*, allegedly found from NCMQ1 deposits in Yushe (Chow, 1963). Better represented in fossils is another form, *D. kirchbergensis* (Xu, 1986), which lived from the beginning of NCMQ2 (Gongwangling) to early NCMQ3 (Dingcun Loc. 90).

By far the richest and most widespread among the Quaternary rhinoceroses is *Coelodonta*. So far no direct ancestral form has been found in pre-Quaternary deposits. However, its Asian origin is beyond any doubt (Kahlke, R. D., 1999; Qiu et al., 2004). The most primitive form, *C. nihowanensis*, was found only in early NCMQ1 (Longdan and Nihewan). The true woolly rhinoceros, *C. antiquitatis*, first appeared in late NCMQ1 in NC (Xihoudu). Fossils of true woolly rhinoceros were widespread in Middle (ZKD) to Late Pleistocene deposits, particularly rich in Northeast China, but may extend to 33°N in central part of China (Chow, 1978).

The existence of the genus *Rhinoceros* in NC is doubtful. The only material referred to this genus (*Rhinoceros* sp.) in NC is the teeth from Nihewan (Teilhard de Chardin and Piveteau, 1930).

Elasmotheres are also a long lasting group of rhinoceroses, ranging from Middle Miocene to Middle Pleistocene in Eurasia. The only genus lived in NCQ was *Elasmotherium*. Some fragmentary teeth and foot bones were found from Xihoudu (*E. inexpectatum*) and Nihewan (*Elasmotherium* sp.). According to Chow (1958), the last appearance of the genus in NC might be *E. peii* in Middle Pleistocene (Pinglu, Shanxi).

3.2.3.3 Tapiridae

As strangers, *Megatapirus* and *Tapirus* occasionally crossed the border between Palearctic and Oriental Realms and shortly inhabited the southern boundary areas of NC. *Megatapirus* was found in Gongwangling, whereas *Tapirus* was recorded in Lochihe (Middle Pleistocene).

3.2.4 Artiodactyla (Fig. 3)

3.2.4.1 Suidae

The evolutionary history of the NCQ suids is poorly understood. Lee (1963) described *Potamochoerus chihnsienensis* from Shanxi, allegedly of early Quaternary age. Xue (1981) created a new species, *Sus subtriquetra*, from Youhe fauna (Middle Pliocene). Affinities of both forms have remained unclear until now. Otherwise, almost all the other fossils found in NCQ were rather arbitrarily attributed either to *Sus lydekkeri*, to the living species *Sus scrofa*, or simply to *Sus* sp. The earliest record of *Sus lydekkeri* might be the fragmentary fossils from Nihewan and Xihoudu. Specimens referable to *S. lydekkeri* were also collected from early NCMQ2 (Gongwangling). In late NCMQ2 fossils of this species already became abundant (ZKD, Lochihe, Miaohoushan, etc.). Ji (1975) referred some specimens from Lochihe Loc. 64112 (Middle Pleistocene) to *Sus* cf. *S. scrofa*. If it proves true, this would be the earliest record of *Sus scrofa* in NC. Fossils of this living species became widespread in NCMQ3 (Sjara-osso-gol, many localities in Northeast China).

3.2.4.2 Camelidae

It is commonly believed that the camelids migrated into Eurasia in latest Miocene together with the canids. The only genus recognized from Pliocene to Middle Pleistocene in NC is *Paracamelus*. Type of *P. gigas* was found from Honan (Zdansky, 1926), probably of NCMQ1 age. A few limb bones of *P. gigas* were recorded from Nihewan. *Paracamelus gigas* persisted into ZKD Loc. 1, where articulated hind limb bones were collected (Young, 1932). In NCMQ3 only one

species, *Camelus knoblochi*, existed (Sjara-osso-gol), probably adapted to desert, semi-desert living condition.

3.2.4.3 Cervidae

The muntjaks evolved rapidly and became rather diversified in Pliocene in Asia, but during the Quaternary they retreated to the southern part of the continent and became one of the dominant elements of the Oriental Realm. In NCQ only a few fossils were described. Chow (1956) described *Muntiacus fenhoensis* from basal sand deposits of the Fenhe riverbank (Shanxi), presumably of Late Pliocene or Early Pleistocene age (now early NCMQ1). Another species, *Muntiacus bohlini*, was recorded in other early NCMQ1 deposits in NC (Nihewan, ZKD Loc. 18). *Elaphodus cephalophus*, a typical animal of Oriental Realm, was reported from Gongwangling fauna (Hu and Qi, 1978).

Cervinae are one of the 2 most diversified groups of ungulates in NCQ. Altogether there were 6 genera recorded: *Nipponicervus*, *Sinomegaceros*, *Cervus*, *Axis*, *Eucladoceros* and *Elaphurus*.

Nipponicervus longdanensis was discovered from Longdan (Qiu et al., 2004). It may be a descendant of some Pliocene *Cervavitus* species. According to Qiu et al. (2004), this genus may also be present in some other early Quaternary deposits (Nihewan, Lochihe Loc. 64102, and possibly Yushe).

The earliest *Sinomegaceros* material was found in Middle Asia, from Late Pliocene Kuruk-sai Formation in Tadzikistan; *S. tadzikstanis* (Vislobokova and Hu, 1990). In NC the earliest appearance of the genus was from Gongwangling, where a primitive species, *S. konwanlinensis*, was described (Hu and Qi, 1978). Slightly later, at ~1 Ma, the most representative Chinese giant deer, *S. pachyosteus* and *S. flabellatus*, appeared in Kehe (Jia et al., 1962). The most abundant fossils of these 2 species were found in ZKD. They were also recorded in Brunnes-Matuyama boundary area of the Wucheng loess section and Chenjiawo (Yue and Xue, 1996). Another species, *S. lochuanensis*, was described by Xue (1982) from the basal part of S5 in Luo-chuan loess section (dated as 0.58 Ma in Ding et al., 2002). In NCMQ3 the predominant form is *S. ordosianus* (Sjara-osso-gol, Loufangzi, Dingcun, Xujiayao, etc.). Giant deer with bizarre antlers were also developed in NCMQ3: *S. baotouensis*, *S. ordosianus mentougouensis* (Huang et al., 1989) and *S. sangganhoensis* (Wei, 1983).

The genus *Cervus* in NCQ comprises mainly of 2 lineages: 1) The sika deer, comprising of *C. (Sika) grayi* and *C. (S.) nippon*; and 2) The red deer, *Cervus (Cervus) elaphus*. The earliest record of sika deer, *C. (S.) grayi*, is from Gongwangling. Next is from Kehe, where the material, however, is inadequate for reliable identification. This species might densely populated in some areas during Middle Pleistocene, for example, ZKD, where more than a thousand of individuals were registered. Its fossils were also found in many other localities of NCMQ2 age (Chenjiawo, Jinniushan) and NCMQ3 (Xujiayao, Dingcun Loc. 100, Loufangzi, Shanchengzi assemblage of Miaohoushan, etc.). The only reliable record of *Cervus (S.) nippon* was reported from ZKD Upper Cave, where more than 30 skeletons were found in "lower recess" (Pei, 1940). *Cervus (C.) elaphus* appeared later than *C. (Sika) grayi*. Its earliest record was the fossils from Jinniushan (late NCMQ2), described by Zheng and Han (in Zhang, 1993). The red deer fossils became more numerous than sika deer in NCMQ3. They were found in Dingcun Loc. 100, Sjara-osso-gol, Loufangzi, Rouyuan, etc.

Nowadays *Axis* is confined to Oriental Realm. However, its fossil forms were widespread in Pliocene in NC. Earliest fossils of this genus were collected from Nihewan, where the fossils originally referred to *Cervus (Rusa) elegans* were transferred to *Axis shansius* (Teilhard de Chardin and Trassaert, 1937). Antlers from Xihoudu were referred to 2 species: *Axis shansius* and *Axis rugosus*. Some specimens of the later species were also recorded from other NCMQ1 localities (Lochihe Loc. 64096 and 64103). After that no fossils of *Axis* have ever been found in

NCQ.

Eucladoceros is a highly specialized deer occurred only in Eurasian Quaternary. In NCQ it is confined to NCMQ1. According to Yue and Xue (1996), *Eucladoceros* was found in S31 in Luochuan loess section (~ 2.3 Ma in Ding et al., 2002). Abundant fossils of *Eucladoceros boulei* were collected in Nihewan. Fossils of this species were also found in other NCMQ1 localities (Yushe and Gonghe).

Elaphurus is another endemic deer of NCQ. *Elaphurus bifurcatus* was established based on sample from Nihewan. Two species, *E. bifurcatus* and *E. chinnaniensis*, were reported from NCMQ1 (Xihoudu, Yangguo). Fossils of the surviving species, *Elaphurus davidianus*, were only found from Holocene (NCMQ4) in archaeological sites.

3.2.4.4 Bovidae

There are 4 gazelline species now living in NC: *Gazella subgutturosa*, *G. picticaudata*, *G. przewalskii* and *G. gutturosa*. The 3 latter species are also often referred to another genus *Procapra*. The genus *Gazella* (s.l.) rapidly diversified and flourished during late Miocene and Pliocene in Eurasia. *Gazella blacki*, primarily a form of Pliocene, might have persisted into early NCMQ1 (unpublished material from Longdan, Xihoudu). On the other hand, according to Chen (1997), although mainly an early NCMQ1 form (Nihewan, Bajiazui, Yangguo, etc.), *Gazella sinensis* might have appeared in Middle Pliocene (Yushe). The earliest record of *G. przewalskii*, a partial lower jaw, was reported from the Dali Man Site (late Middle Pleistocene) by Zhang and Zhou (1984). *Gazella* fossils became more abundant in NCMQ3 (Xujiayao, Sjara-osso-gol, Loufangzi, Rouyuan, etc.).

The most important Quaternary antilopines in NC are *Antilospira* and *Spirocerus*. Their history can be traced back to Pliocene. *Antilospira* persisted into early NCMQ1. Remains of *A. licenti* were found in Nihewan. The earliest Quaternary *Spirocerus*, *S. wongi*, with moderately twisted horn cores with anterior keels, was collected from Nihewan. Another species, *S. peii*, with horn cores provided with both anterior and posterior keels, is mainly a Middle Pleistocene form (ZKD). However, it might be partly contemporaneous with *S. wongi*. According to Yue and Xue (1996), it was found in the interval 61 ~ 103 m of the Wucheng loess section, which is dated as 1.6 ~ 0.7 Ma in Ding et al.'s Chiloparts. According to Jia et al. (1979), the fossils from Sjara-osso-gol, referred to *S. kiakhtensis*, is different from the type described by Pavlova in 1910 and should be a new species, named as *S. hsuchiayaocus*. However, Kahlke (1999) continued to regard *S. kiakhtensis* as a valid species. Thus, Middle Pleistocene is characterized by *S. peii*, while NCMQ3 by *S. kiakhtensis*. The latter form was considerably widespread in North China, and particularly in Northeast China.

Reliable and important Caprinae of NCQ comprise only *Ovis* and *Capricornis*, represented only by a few fossils. The earliest sheep found in NCQ is *Ovis shantungensis*, described by Teilhard de Chardin and Piveteau (1930) from Nihewan. The living species *Ovis ammon* first appeared in NCMQ3 (Sjara-osso-gol, Loufangzi, etc.). *Capricornis sumatraensis qinlingensis* was apparently an Oriental element invaded into NC. It was recorded only from Gongwangling.

Bovinae constitute the next to cervids important group among the NCQ ungulates, comprising *Hemibos*, *Leptobos*, *Bison*, *Bos* and *Bubalus*.

Hemibos was only recorded in one place, Longdan, where *H. gracilis* was described. *Leptobos* is the most important bovine form in NC, lived mainly in NCMQ1. *Leptobos brevicornis* and *L. crassus* were discovered in a series of early NCMQ1 localities (Longdan, Xihoudu, Yangguo). *Leptobos brevicornis* can also persist into Gongwangling.

Bison is a bovine genus developed only in Quaternary. Reliable finds of the first *Bison* is that described from Nihewan, named as *B. palaeosinensis*. Its fossils were also found from other NCMQ1 deposits (Haiyan, Bajiazui, Xihoudu, Yangguo). Fossils referable to, or close to the recently extinct *Bison priscus* were frequently met in NCMQ3 in Northeast China.

The only representative of the genus *Bos* found in NC is *B. primigenius*. Its earliest record in NC may be that listed in Xujiayao fauna by Jia et al. (1979). However, its presence in this fauna is to be further verified. Fossils of *B. primigenius* became very common in NCMQ3 (Dingcun, Sjara-osso-gol, Loufangzi, Rouyuan, etc.). Its remains can even be found in archaeological sites in NCMQ4 (Xiwanggang, Yinxu in Henan).

Fossils of *Bubalus* were frequently met in NCQ. The earliest appearance of this genus might be the fossils of *Bubalus teilhardi* from Kehe (early NCMQ2). However, morphologically the most primitive species should be *B. brevicornis*, created by Young (1936) from Mianchi, Henan, which might be early Middle Pleistocene in age (Chow and Hsu, 1957). The possibility that the deposits bearing the type specimen of *B. brevicornis* is earlier than so far thought can not be ruled out yet. Another species, *B. tingi*, might be also a form of late NCMQ1 (Anderson, Lok. 105, Yuzicun, Yuanqu), judging by the associated forms like *Sivapanthera pleistocaenicus*, *B. brevicornis* and *Meles chiai*. Abundant fossils of *Bubalus* were collected from Middle Pleistocene (ZKD). In NCMQ3 different species of *Bubalus* were reported: *Bubalus* sp. from Dingcun, *B. youngi* from Mengxian, Hennan, *B. wansjocki* from Sjara-osso-gol, etc. In Holocene *B. mephistopheles* was recorded from the Archaeologic Site of Anyang (Teilhard de Chardin and Young, 1936).

4 Evolutionary phases of NCQ large mammals

Traditional practice of paleontologists studying Quaternary mammals in past century had been to try to precisely tie mammalian faunas to conventional Quaternary time scale and to characterize these faunas in the frame of the Quaternary subdivisions, named as Early, Middle or Late Pleistocene mammalian fauna, etc. With the introduction of the MIS system into the Quaternary geochronology, attempts to correlate mammalian faunas with MIS data have been made worldwide recently. The studies carried out by Xu Qinqi in the last decades may serve as such example happened in China. Xu (1990) listed 9 events of LSD and HSD of certain mammalian forms and correlated them with the MIS curve in great detail. While Xu's method concerned mainly individual mammalian forms, we would like to stress the phase aspect in mammalian evolution. In fact, taking the evolutionary history of individual forms in conjunction with the faunal changes in composition into account, we may likely succeed in dividing the seemingly continuous faunal sequence into different phases characterized by different evolutionary levels. In doing so we succeeded in distinguishing 4 large mammal phases in NCQ. The time duration of these 4 phases are: 2.6 ~ 1.3 Ma, 1.3 ~ 0.13 Ma, 0.13 ~ 0.011 Ma, and 0.011 Ma ~ Present. We would like to call them provisionally as NCMQ1 - 4 (from earliest to latest). It is important to note that not all of these phases coincide with the conventional subdivisions of the Quaternary. So far the above proposed subdivision of the Quaternary large mammal faunas can only be applied to North China.

4.1 NCMQ1 (2.6 ~ 1.3 Ma)

This phase is characterized by the turnover from *Hipparion* faunas into *Equus* faunas and the formation of the archaic *Equus* fauna, spanning from Late Pliocene (Gelasian) to the middle of Early Pleistocene.

By the end of Pliocene (2.6 Ma) majority of the most representative elements of the *Hipparion* faunas became extinct, such as the mustelids: *Sinictis*, *Eomellivora*, *Parataxidea*, *Promephitis*, *Plesiogulo*; the ursids: *Indarctos*, *Agriotherium*; the hyaenids: *Ictitherium*, *Thalassictis*, *Hyaenictitherium*, *Lycyaena*, *Adcrocuta*; the felids: *Machairodus*, *Paramachairodus*, *Metailurus*; the proboscideans: *Anancus*, *Mammut*; the perissodactyls: *Hipparion* with exception of *H. (Proboscidihipparion)*, *Chilotherium*, *Acerorhinus*; the artiodactyls: *Palaeotragus*,

Samotherium, *Honanotherium*, *Urmitherium*, *Plesiaddax*, *Metacervulus*, *Paracervulus*, *Protoryx*, *Paraprotoryx*, *Sinoreas*, *Lyrocerus* etc. On the other hand, at 2.6 Ma or slightly later, a large number of new genera appeared either as immigrants from North America, as *Equus* and *Megantereon*; or evolved directly from Eurasia, as *Eirictis*, *Meles*, *Crocota*, *Coelodonta*, *Muntiacus*, *Eucladoceros*, *Elaphurus*, *Leptobos*, *Bison*, etc. Some forms belong to genera already existed in pre-Quaternary, but evolved into new species highly characteristic of Quaternary, often giving origin to the important living animals of Paleoafrican Realm, like the Quaternary species of *Vulpes*, *Nyctereutes*, *Canis*, *Paracamelus* of North American origin; *Ursus*, *Pachycrocuta*, *Homotherium*, *Lynx*, *Sivapanthera*, *Mammuthus*, *Nipponicervus*, *Antilospira* of Eurasian origin, etc. This phase demonstrates the greatest faunal replacement since the formation of the *Hipparion* faunas in Eurasia.

For about half a century since 1948, the first appearance of *E-L-E* (*Equus-Leptobos-Elephas*) had been regarded as the marker of the beginning of Quaternary. If the lower boundary of Quaternary would be fixed at 2.6 Ma as might be adopted in the near future, the first appearance of *Leptobos* would remain valid. The *Equus* might have occurred in Eurasia earlier as some of the former Soviet Union authors advocated (e. g., Vislobokova et al., 2003). Whether this latter opinion is tenable should be further verified. At any rate the rapid differentiation and territorial expansion of the genus *Equus* in Eurasia since 2.6 Ma is a fact widely accepted among vertebrate paleontologists. As regards *Elephas*, the situation changed radically. Firstly, the opinion as to the contents of the genus *Elephas* differs widely. In opinion of some authors, *Elephas* appeared evidently in pre-Quaternary time. Secondly, the most representative forms of Eurasian Quaternary proboscideans belong not to *Elephas*, but to *Mammuthus*, which evolved also from pre-Quaternary time.

It seems that this phase persisted until to the middle of Early Pleistocene (~1.3 Ma).

The above described faunal turnover and persistence of the first phase of Quaternary mammalian faunas are in good accordance with the climatic change as evidenced by the onset of the loess deposits in NC and the TB3.8 lowest sea level stand in sequence geology (*vide supra*).

4.2 NCMQ2 (1.3 ~ 0.13 Ma)

Considerable faunal changes occurred around 1.3 Ma. By this time the following genera could have become totally extinct, at least in NC: *Eirictis*, *Chasmaporthetes*, *Paracamelus*, *Axis*, *Nipponicervus*, *Eucladoceros*, *Antilospira*, *Hemibos* and *Leptobos*. Majority of the forms characteristic of Middle Pleistocene as exemplified by the ZKD fauna appeared around 1.3 Ma. As new genus or subgenus *Sinomegaceros* (but appeared earlier in Central Asia) and *Cervus* (*Sika*) appeared. At the same time a series of more advanced or specialized species derived from NCMQ1 became dominant and highly characteristic of the Middle Pleistocene. These are: *Canis variabilis*, *Pachycrocuta sinensis* (from *P. licenti*), *Megantereon inexpectatus* (from *M. nihowanensis*), *Panthera tigris* (from *P. palaeosinensis*), *Dicerorhinus kirchbergensis* (from *D. yunchuchenensis*), *Coelodonta antiquitatis* (from *C. nihowanensis*). At about the lower boundary of Middle Pleistocene (~0.78 Ma) or later, more forms characteristic of Middle Pleistocene appeared: *Cuon alpinus*, *Nyctereutes procyonoides*, *Ursus arctos*, *Meles meles*, *Sus scrofa*, and *Cervus elaphus*.

A peculiar aspect of this phase is the invasion of some Oriental elements into the south border areas of NC at the beginning of this phase, including *Rhinopithecus*, *Ailuropoda*, *Stegodon orientalis*, *Tapirus*, *Megatapirus*, *Elaphodus* and *Capricornis*. Opinion as to whether such an invasion represents a warm climate event differs widely. An et al. (1990) correlated the Gongwangling loess section with that of Luochuan and concluded that the mammalian fauna with *Homo erectus* remains was found from the sandy loess layer correlatable with L15 in Luochuan section and its age should be 1.15 Ma. An et al. argued that although the sandy loess of L15 indicated a

dry-cold climatic condition, some Oriental elements could cross the Qinling Mountains and entered the south part of the Loess Plateau through low cut passage way. Sun and Liu (2002) correlated L15 with MIS 34, dated as 1.1 Ma, and considered the coarse-grained L15 rather the product of rapid lifting of the Qinling Mountains than of dry-cold climate. Huang Weiwen (in Liu et al., 2000) doubted An et al.'s correlation and considered the fossil-bearing layer as belonging to some paleosol layer, and dated it as old as 1.8 Ma. Ding et al. (2002) stressed the marked coarsening of L9, L15 and L32 in their newly suggested Chiloparts. As is clearly seen in the Chiloparts, the L15 is here correlated with MIS 38 (~1.25 Ma). The grain size change between L15 and L32 is rather weak, implying a generally mild climatic condition, whereas the grain size curve above L15 fluctuates markedly, indicating a strong tendency of climatic deterioration. It seems more probable to us that the Gongwangling fossil-bearing layer represents a paleosol slightly earlier than L15 and represents a warm time period, permitting invasion of some Oriental elements into the Loess Plateau.

Pending further study of mammalian faunas and more precise dating, we may note that the NCMQ2 phase can be further subdivided in the future. As is indicated above, the S5 might be a rather long period of mild climate (0.62~0.48), which is partly, but clearly demonstrated by the particularly rich ZKD faunas. As the Chiloparts show, above and below this mild period the climate became unstable and considerably deteriorated. If this may prove true, NCMQ2 could well be further separated as NCMQ2a~c in the future.

4.3 NCMQ3 (0.13~0.011 Ma)

This phase is characterized by the appearance of a series of living species, like *Equus przewalskii*, *E. hemionus*, *Sus scrofa*, *Gazella przewalskii*, *G. subgutturosa*, *Ovis ammon* etc. The cold weather adapted and usually abundantly represented forms characteristic of Late Pleistocene include *Mammuthus primigenius*, *Coelodonta antiquitatis*, *Bos primigenius*, *Bison priscus*, and various giant deer with bizarre antlers like *Sinomegaceros ordosianus*, *S. ordosianus mentougouensis*, *S. baotouensis* and *S. sangganhoensis*. *Alces alces*, a form of tundra fauna, was recorded only in Northeast China. However, no records of extremely cold-adapted forms often found in Siberia, such as *Alopex lagopus*, *Rangifer tarandus* and *Saiga tatarica* were ever found in NC or Northeast China.

4.4 NCMQ4 (0.011 Ma ~ Recent)

During this phase the fauna became modernized by disappearance of the cold weather adapted NCMQ3 forms, like *Mammuthus*, *Coelodonta*, *Sinomegaceros*, *Alces*, *Bos primigenius*, *Bison*, etc., and the archaic forms of the Oriental Realm, like *Crocota*, *Acinonyx*, etc.

The above four-fold subdivision of the Quaternary based on large mammal faunal evolution does not fully coincide with the conventional subdivision of the Quaternary, i. e., Late Pliocene, Early, Middle, Late Pleistocene and Holocene. The NCMQ1-2 boundary lies at 1.3 Ma. On the other hand, no sharp faunal changes can be detected at about the Pliocene-Pleistocene boundary (1.8 Ma) and at the Early-Middle Pleistocene boundary (0.78 Ma). However, such a subdivision is highly congruent with the climatic changes obtained from the loess section. It is also interesting to note here that such a subdivision seems closer to the faunal zonation currently widely adopted in Europe and North America. According to De Giuli et al. (1987), in Europe the Villafranchian starts at about 3.5 Ma and ends at the time span between 1.4 Ma and the beginning of the Jaramillo Paleomagnetic event (1.07 Ma). In North America the Quaternary encompasses the later part of the Blancan, Irvingtonian and Rancholabrean Land Mammal Ages (NALMA). The lower boundary of Blancan extends to 4.6~5.2 Ma, but ends at about 1.35 Ma based on the first appearance of *Mammuthus* in North America (Bell et al., 2004). Both of

these boundaries are close to the age of the NCMQ1-2 boundary (1.3 Ma). Furthermore, in North America the time duration of the Irvingtonian covers more than 1 myr (1.35 ~ 0.2 Ma), very close to that of the NCMQ2 (1.3 ~ 0.13 Ma) as well.

Acknowledgements Thanks are given to Prof. Deng Tao for his help in preparation of the figures.

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