

## The Palaeoenvironmental Changes and Macromammal Evolution during the Pleistocene in East Asia

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### 동아시아의 제 4 기 자연환경의 변화와 젓먹이근동물의 제 4 기적 진화

박 선 주

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#### ABSTRACT

The understanding of the faunal sequence and palaeoenvironment of East Asia since the Late Tertiary depends mainly on the knowledge of Chinese fauna and its environmental changes. The recent Chinese researches including geology, geomorphology, climats fluctuation and loess distribution of this area have provided that the rapid uplifting of Himalayas and Qinghai/Xizang Plateau since the Lower Pleistocene was a main selective factor for the process of environmental changes in this vast territory. Although different concepts of the Plio-Pleistocene boundary have been provided, its boundary can not exceed over 2 mya.

Instead of the traditional zoogeographical dichotomy in China, faunal compositions of Pleistocene are divided into three faunal zones. The knowledge of macrofaunal evolution in China are useful to understand the palaeoecology of East Asia. Palaeoenvironment of Korea during the Pleistocene Period can be reconstructed by using the analogy of the current Chinese studies.

#### 요 약

중국과 한국을 포함하는 동아시아에 제3기말기 이후 제4기홍적세 시기에 살았던 동물상의 연구와 자연환경의 연구는 주로 중국에서 이루어졌다. 최근 중국에서 이루어진 이 지역에 관한 지질학, 지형학과 기후의 변화 및 loess의 발달등

에 관한 연구들은 초기 홍적세 시기에 진행되었던 히말라야와 칭하이/신장 고원의 빠른 융기 작용이 동아시아에서 진행되어온 자연환경의 변화에 커다란 영향을 미쳤음을 보여주고 있으며, 홍적세의 상한 또한 2백만년을 넘을 수 없음을 밝혀 주고 있다.

전기 홍적세 이후로 중국에서의 동물군은 크게 북중국, 남중국 그리고 중간지역 등의 3개의 동물군으로 나눌 수 있으며, 젓먹이근동물의 발달과정을 통해서 홍적세시기의 생태계를 이해할 수 있다. 한국선사시대 환경과 동물상은 같은 시기에 속하는 북중국의 자연환경 및 동물상과 비슷하였음을 알 수 있다.

## INTRODUCTION

An understanding of Pleistocene fauna in East Asia depends heavily on a knowledge of Chinese fauna. There are two main reasons for this; 1) Chinese faunas represent both tropical and temperate mammalian assemblages which provide a key link between southern Asian, temperate Eurasian, and African assemblages, and 2) China has received the major focus of paleontological research in comparison to anywhere else in Asia.

This paper focuses on the natural environment and its evolution in China during the Pleistocene Period, including geology, geomorphology, climate fluctuation, and loess distribution. Different concepts of the Plio-Pleistocene boundary will also be examined. Faunal studies will be mentioned based on the recent researches by Chinese scholars. This paper is a part of an overall project whose aim is to make preliminary steps in the understanding of the Korean faunal sequence and palaeoenvironment during the Pleistocene Period. It is assumed that Korean fauna and natural environment have been influenced by those of continental China, especially by environmental changes in northern and northeastern China during the Quaternary. Studies of the Chinese Quaternary are greatly helpful in understanding the Korean Quaternary.

## PALAEOENVIRONMENTAL CHANGE SINCE THE LATE TERTIARY

### 1. Geology/Geomorphology/Palaeogeography

China occupies a vast territory in East Asia. Two latitudinal and one longitudinal line divide China into five major natural regions; South China, North China, Northeast China, Qinghai-Xizang and Northwest China (Zhang 1980). The distribution of these five major natural regions is closely related to the structure of the earth's crust which represents the five large blocks of continental crust in China.

Through the Late Pliocene, the Himalayas and the Qinghai/Xizang Plateau rose due to the movement of the Indian Plate against Laurasia. During the Quaternary the Himalayas and the Xizang Plateau were rapidly uplifted. In the Lower Pleistocene, the Xizang Plateau was approximately 3,000m to 4,500-5,500m in elevation (Liu, *et al.* 1984).

Simultaneously, uplifting was occurring in the mountains of North China. Inner Mongolia, Shanxi, Shaanxi and a portion of Gansu became table-lands; loess blanketed much of North China. Judging from palynological data, the Qinling Mts. might have reached its present altitude after the Lower Pleistocene. Uplifting of Plateau was responsible for environmental changes in China, especially in the increasing spread of loess and redistribution of laterite during the Pleistocene period, and changes in atmospheric circulation.

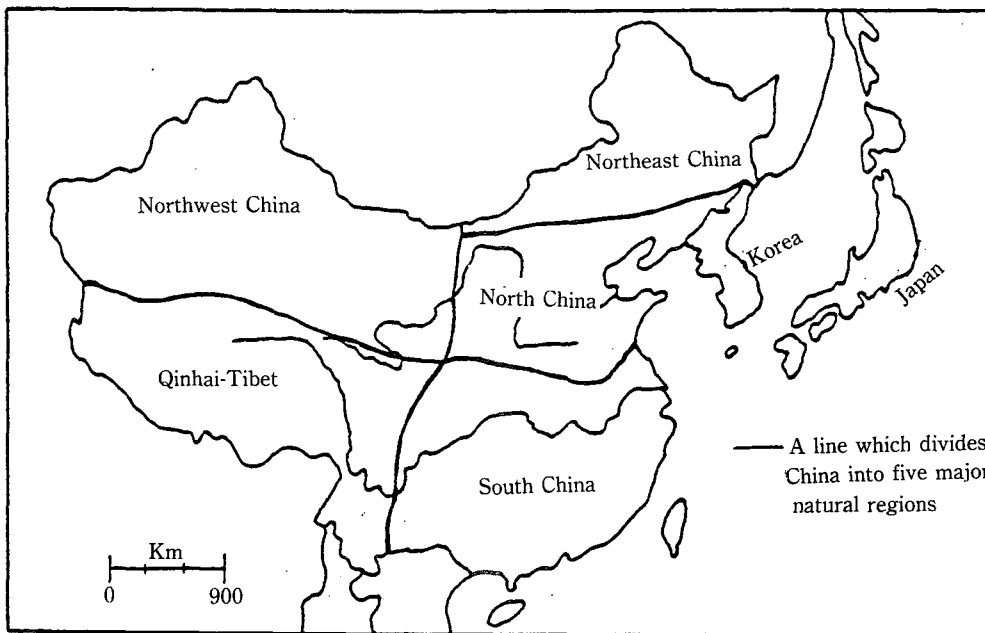


Fig. 1. Five major natural landscape regions (From Zhang, 1980)

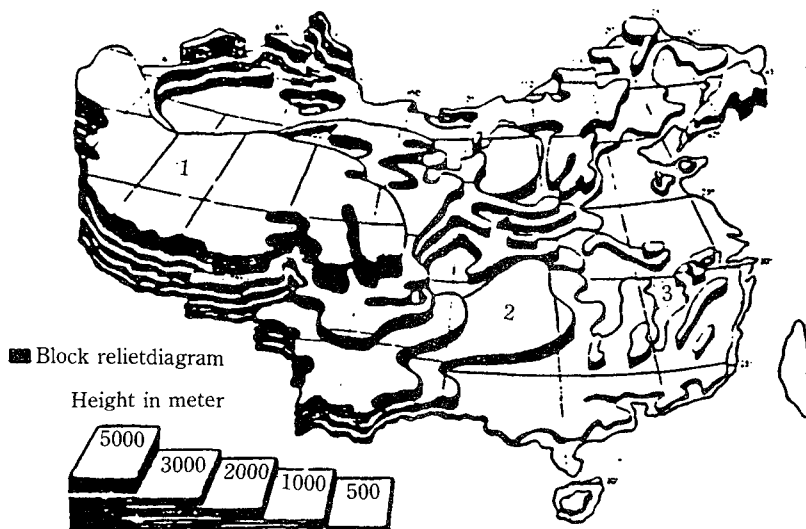


Fig. 2. 1. Topology of China  
(From Atlas of China: Chias-min Hsieh, 1972)

- 1: The Qinghai/Xizang plateau '4000m'
- 2: The surrounding area of Qinghai/Xizang (1000-2000m)
- 3: Plains and hilly lands (200-500m)

The topology of China resembles a series of steps decreasing in height from west to east. The first step is the Qinghai/Xizang Plateau, with an average altitude of about 4,000m above sea level (W/E 3,000 Km × 1,500 Km N/S). The second step is the surrounding areas of

Qinghai/Xizang, including Inner Mongolia, Xinjiang, Shanxi, Shaanxi (Loess) and Yunnan and Guizhou Plateau (1,000-2,000m altitude). The third step is composed of plains and hilly lands in the eastern region with 200-500m average altitude. The step-like geological formation of

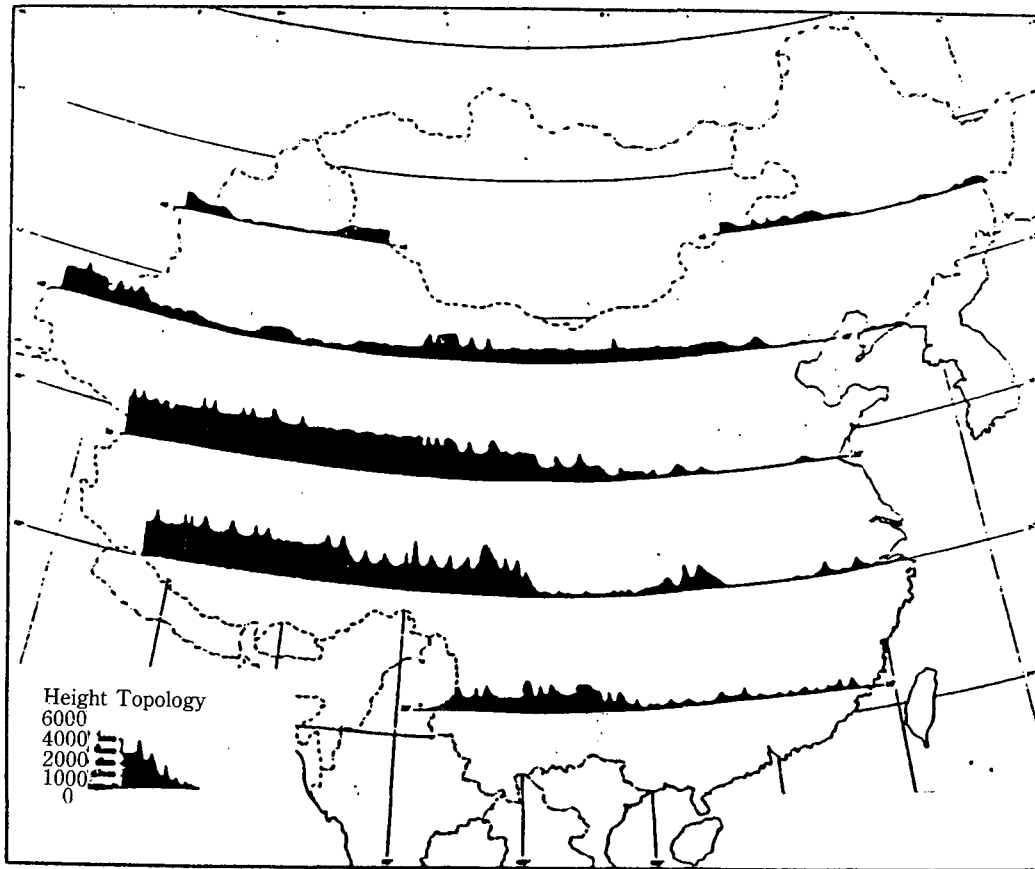


Fig. 2.2 Cross section of Topology of China

China came into being during the Middle to Upper Pleistocene (Liu, 1984) (Fig. 2.).

The distribution pattern of Quaternary sediments in China is closely related to geomorphic patterns and natural climatic zones. During the Upper Pleistocene, East and West China reveal significantly different natural environments, namely horizontal zonation from the north to south in the east by the Qinling, and vertical zonation in the west by the Qinghai/Xizang Plateau (Liu 1984).

According to the "Map of distribution of Quaternary sediments in China" (Liu, *et al.*, 1984), East China is divided into two sections: the south tropical zone and the north temperate zone by the Qinling Mts. The soil deposits in North China are characterized by the development of loess which are yellow in color, and rich

in Ca, and alkaline in nature; this indicates a dry, cold climate. The laterite in South China, which is red in color, rich in Fe and Al, and is an acidic soil, is the typical soil deposit which indicates a warm, wet climate. In northeastern China deposits show the development of black earth. In West China mountain glacial moraines, glaciofluvial sediments, and permafrost are the main characters of the deposits. In arid northwestern China gravels (Gobi), sand dunes and loess are the main dominant deposits.

One of the major impacts of Plate tectonics in the Neogene in East Asia (the movement of the Indian plate and its collision with Laurasia, the rise of the Himalayas and Qinghai/Xizang Plateau) is the changes in the basic shape of the Pacific coastline in East China (Fig. 3).

During the Lower Pleistocene, the Pacific

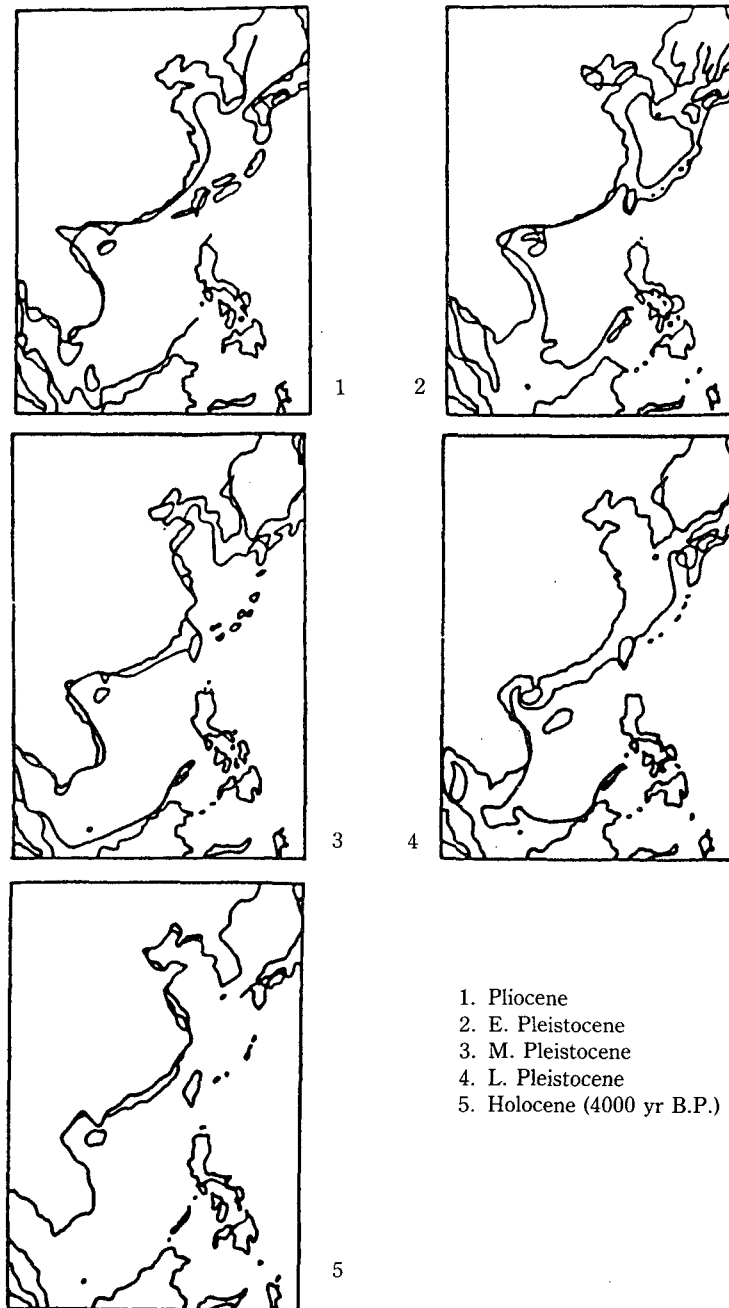


Fig. 3. Coastline changes during the Plio-Pleistocene in East Asia  
 (Based on Liu and Ding, 1984)

shore line regressed eastward resulting in a land connection between Taiwan and the continent. However, sea water still invaded the North China Plain. During the Middle Pleistocene sea water ingressed from the East China Sea and the South China Sea into the continent and ex-

panded to form the North Huang Hai (Yellow Sea). During the Upper Pleistocene, the maximum regression line was located 110 to 120 m below the present sea level, the coastline to the east of the Chang Jiang delta regressed eastward about 600km, and Korea, Japan, and

Hainan Island were connected with the continent. During the Holocene, about 6,000 years B.P., the highest strand line was between 5-10m higher than that of the present day and transgression reached 100km inland (Zhao, 1979; Chang and Wang, 1982).

Xu and You (1982) have tried to establish a correlation between oxygen isotope studies and the sequence of losses distributed mainly in North China for the reconstruction of climate fluctuation. Loess in China, with its wide distribution, depth, and continuous deposition, may be a reliable clue for the correlation of land and sea records of global climatic fluctuation in the Quaternary. Loess, sometimes 130-170m thick, is a geographically wide spread aeolian deposit in China. Biostratigraphic studies indicate that these loess formations can be divided into the Lower Pleistocene-Wucheng loess, yielding a Nihewan fauna (Villafranchian); the Middle Pleistocene-Lishi loess with a Zhoukoudian fauna and *Homo erectus pekinensis*; the Upper Pleistocene-Malan loess; and the present loess (Liu *et al.*, 1984).

Magnetostratigraphic studies (Heller and Liu, 1982; Liu and Ding, 1982) show that an excellent sequence of polarities has been recorded in a typical loess profile 138m thick at Luochuan, Shaanxi province. The Brunhes/Matuyama boundary is situated at 53.05m from the top, jaramilla subchron at a depth of between 67.30m and 72.50m and the Olduvai subchron at between 107.40 and 113.10m. There are two samples near 130m of normal polarity which might fit closely the Reunion subchron; the Matuyama/Gauss boundary is recorded at 138m, which is the base of the Wucheng loess and the top of a clay formation of Late Pliocene age.

A climatic curve obtained from within this part of the Luochuan loess profile (from B/M boundary) shows 8 palaeosol/losses cycles and an uppermost buried palaeosol; 8 climatic cycles

and a subcycle of climatic fluctuations have been established. The nine designated cycles of climatic fluctuation could be correlated with the oxygen isotope records of core V28-238 (Liu and Yuan, 1982).

Many Chinese scientists believe that a better comparison of time and climatic features in palaeofluvial-lacustrine sediments can be made on the basis of loess deposits and cave deposits. They have attempted to provide a correlation between loess profiles and cave deposits at Zhoukoudian. If this correlation is acceptable, it is probable that Peking Man experienced repeated cold/warm climatic changes in Zhoukoudian (Xu and You, 1982).

## 2. Palaeoclimate

Presently, climate zonation of East China generally extends from north to south across cold-temperate, temperate, subtropical and tropical zones. Western China shows different climatic features.

In the Quaternary there was a marked temperature drop, especially during the glacial periods. The mean annual temperature declined 14° to 24°C as compared with the early Tertiary, but fell less in the interglacial periods. Judging from plant fossils found at Weinan (109.5°E X 33.3°N) in Shaanxi province and Pan Xian (104.7°E X 25.8°N) in Guizhou province, the mean annual temperature of the last glacial period (=Wurm Glacial period) was about 8°C lower than the present in eastern China.

Due to the effects of lower temperature and the uplift of mountain ranges, especially the Himalayas, the climate of northwestern China became drier than before. Some dry areas such as the Tarim Basin, western portions of Inner Mongolia and Heilongjiang became semi-deserts or deserts. After the Lower Pleistocene, the Qinling Mts. were gradually uplifted to their present altitude. This uplifting resulted in a bar-

rier which prevented the monsoon winds from the south from passing to North China and also blocked the cold air masses from Siberia from moving into southern China. Subsequently, the climate of northern China has become drier and cooler, and that of southern China wetter and warmer. The Qinling Mts. formed the demarcation line between the climate of the continent to become drier and colder and has led to different climatic features than those of East China. Until recently it had been thought that during the Pleistocene many glaciers existed in eastern China. According to recent investigations there is no reliable evidence of glaciation of the mountains recorded in the eastern part of China (Shi, 1981) with exception of the Dabie Shan of the Qin Ling Ranges and the Xue Shan of northern Taiwan.

#### PLIOCENE/PLEISTOCENE BOUNDARY

The placement of the Plio-Pleistocene boundary has long been a center of controversy amongst geologists. In China four different definitions of the Plio-Pleistocene boundary can be summarized as follows.

1. The Nihewan deposits (Sanmenien deposits) have long been reported of Lower Pleistocene age and contain a Villafranchian fauna. Recently, the Nihewan deposits have been subdivided into the lower Nihewan bed and the upper Nihewan bed. The fauna of the lower Nihewan beds, which shows the same faunal characteristics as the lower part of the Sanmen group or the Yushe group, is comparable with the early Villafranchian fauna of Europe. The upper Nihewan beds could be related with the middle Villafranchian. Therefore, the boundary of the lower and upper Nihewan beds could separate represent Plio-Pleistocene boundary.
2. The Plio-Pleistocene boundary has been reported for the base of the Mammoth event

of Gauss normal polarity epoch or still lower (3.0-3.5MYA). This time range is not in accordance with biostratigraphic studies. This suggestion would include the lower Nihewan deposits (the lower part of the Sanmen group, Yushe group and the Sagou group) in the Lower Pleistocene. Since the fauna from the lower beds correspond to those of the Early Villafranchian of Europe, they probably represent a Late Pliocene fauna.

3. Lochuan loess studies show that the base of the Wucheng loess is 20m below the Olduvai Event (Heller *et al.*, 1982). Based on this study, and the biostratigraphic, lithographic and magnetostratigraphic studies of the intermountain basin deposits, the cave deposits and the maritime plain deposits, it is suggested that the boundary of Matuyama/Gauss Epoch (Ca. 2.43 MYA) could correspond to the Plio-Pleistocene boundary (Liu *et al.*, 1982). According to this study, the boundary between the lower and upper Nihewan deposits, between the Yuanmou deposits (in the narrow sense) and the Sagou deposit, and the boundary of Wucheng loess and the underlying Red Clay, all correspond with the Matuyama/Gauss Epoch boundary.
4. Magnetostratigraphic studies of Nihewan deposits and loess deposits (Zhou, 1984; Li *et al.*, 1984) have put the Plio-Pleistocene boundary at the base of the Olduvai Event, Ca. 1.8 MYA. This definition has been adopted from estimates of the age of the stratotype Plio-Pleistocene boundary in Italy, the base of the Calabrian stage (Van Couvering, 1974).

Based on a re-evaluation of the Calabrian biostratigraphy, using the calcareous non-noplankton, it is suggested that the "boundary-stratotype" at Le Castella should be correlated to the top of the Olduvai Event, at about 1.6 MYA (Hag *et al.* 1977). Van Couvering (1978)

reports that this new data is in close agreement with ages associated with a marked climatic deterioration seen in Atlantic cores and with Nebraskan continental glacial deposits and fauna.

A recent joint meeting of the INQUA Subcommission 1-a (=ICS Working Group N/Q Boundary) and the IGCP Project 41 in the Int. Ge. Congress (1980, Paris) concluded that "the N/Q boundary should be placed in the Vrica section taking into account the first appearance of datums (FAD) of the early cold guest *Cytheropteron testudo* (whatever its palaeoclimatic significance could be), which occurs in Vrica 10m above Sapropel *e*. On the other hand, there are alternative possibilities for selecting a level as the N/Q boundary stratotype in the Vrica section, within the stratigraphical interval level *e* and the volcanic ash level *m*, which are closely related with the FAD of *C. testudo*, within a reasonable short time range." (Obradovich, 1982)

Obradovich *et al.* (1982) suggest that although estimates of the age of the stratotype Plio-Pleistocene boundary in Italy range from 1.65 to 2.5 MYA, the proposed Plio-Pleistocene Boundary stratotype in the Vrica section will fall close to 1.7 MYA and that all other published estimates suggesting an age of 2 MYA or more are inappropriate. This age based on biostratigraphic criteria—the first appearance datums (FADs) and last appearance datums (LADs) of planktonic foraminifera and calcareous nannoplankton tied to the magnetic reversal chronology.

Presently, it has been widely accepted amongst the Chinese geologists that the Plio-Pleistocene boundary of China can be adopted from the base of Calabrian stage, Ca 1.8 MYA.

## PLEISTOCENE MAMMALIAN FAUNA IN CHINA

### 1. The Zoogeographical Province of China

The Pleistocene mammalian faunal record in China shows that: 1) the structural and compositional differences between the living faunas of the two zones extend well back into the Tertiary; 2) the boundary between faunal zones existed at approximately its present location through the late Cenozoic; and 3) the faunas of northern China repeatedly reveal strong influence from other parts of Eurasia during the late Cenozoic, while those of southern China have a long history of relative isolation (Kahlke, 1961; Luchterhand, 1978, 1985).

The major zoogeographical dichotomy in eastern China is broadly divided into two sections throughout the Pleistocene: one portion palaeoarctic, a northern temperate faunal zone; and one palaeotropical or Oriental Realm, a southern tropical zone. The boundary between these major faunal zones corresponds to major transitions in fauna, flora, vegetation and climate (Darlington, 1957; Wang, 1961; Zhang and Zhao, 1978).

Zhang and Zhao (1978) place the present boundary between the Palaeoarctic and Oriental realms in eastern China at about 35 north latitude which consists of a line running from the Himalayan massif in the southwest through the Qinling Mts. of east-central China to the middle and lower reaches of the Yangzi River. They divide the continent of China into seven zoogeographic provinces, each with internal divisions. These zoogeographic divisions correspond closely to Liu *et al.*'s (1984) analysis of present climatic and topological features of China. The boundary of these two major fauna zones in East China also corresponds quite closely to Wang's (1961) transition from deciduous broadleaf to mixed mesophytic forests in the living flora.

Following Zhang and Zhao's (1978) zoogeographical divisions, Luchterhand (1984) modifies the mammalian fauna of China with



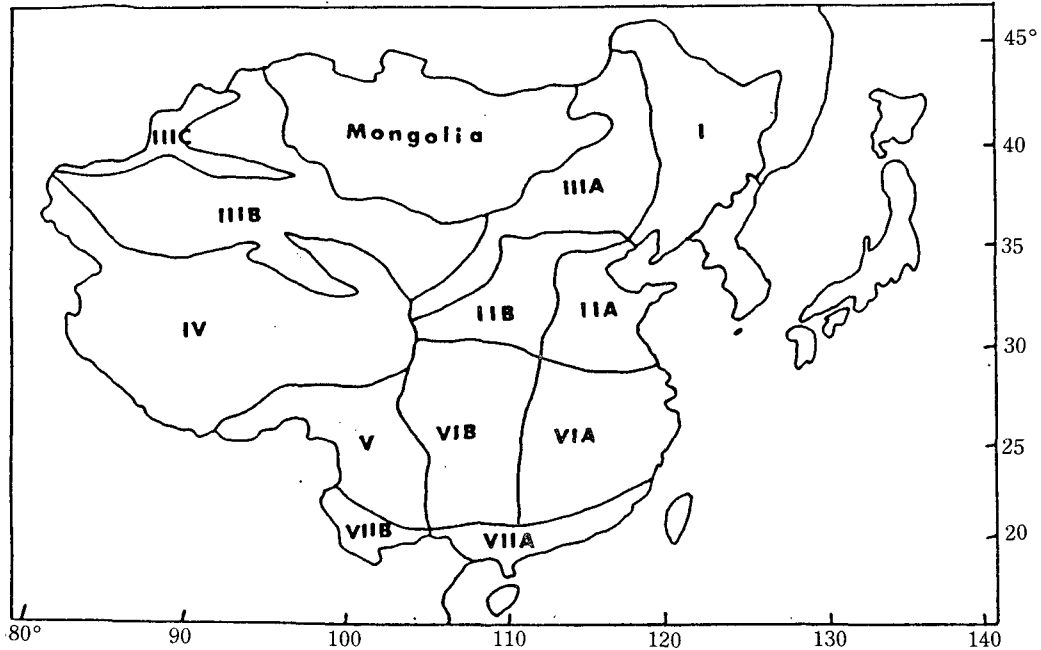


Fig. 4. The Zoogeographic provinces of China (From Zhang and Zhao, 1978)

Palearctic realm:

I) Northeast China region; II) North China Region with western and eastern subregions; III) Nei Monggol-Kinjiang region, with subregions; IV) Qinghai/Xizang region.

Oriental realm:

V) Southwest China region; VI) Central China region, with western and eastern subregions; VII) South China region

western and eastern areas, and with northern and southern areas of China using analysis of distribution of modern living terrestrial mammals.

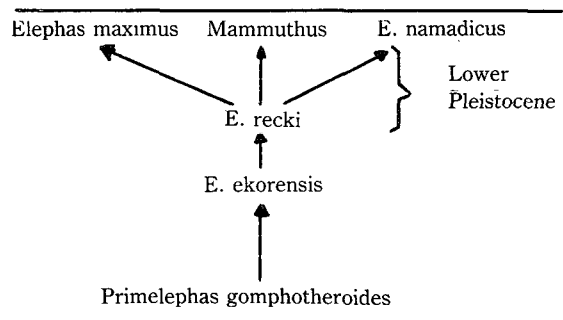
## 2. Mammalian Evolution in China

### A. The Proboscidea

The Proboscidea is one of the important mammalian orders allowing correlations between faunal localities, especially in southern China. Stegodontidae, Gomphotheridae and Mammutidae were widespread throughout the Old World in the Neogene and Quaternary. The Elephantidae in China were an autochthonous family except for *Elephas planifrons*. Over 75 species have been described from China alone, but many of these are undoubtedly synonyms (Pope, 1982).

The great diversity arose during the Pliocene. Tobien (1984) suggests two probable local evolutionary lineages of mastodons in China; one lineage is obviously represented by Gomphotherium Tetralophodon Anancus, the other by *Zygodon* cf. *Zygodon* (advanced) *Mammut*.

Among Elephantidae, Maglio (1973) concludes that *E. maximus*, *Mammuthus*, and *E.*



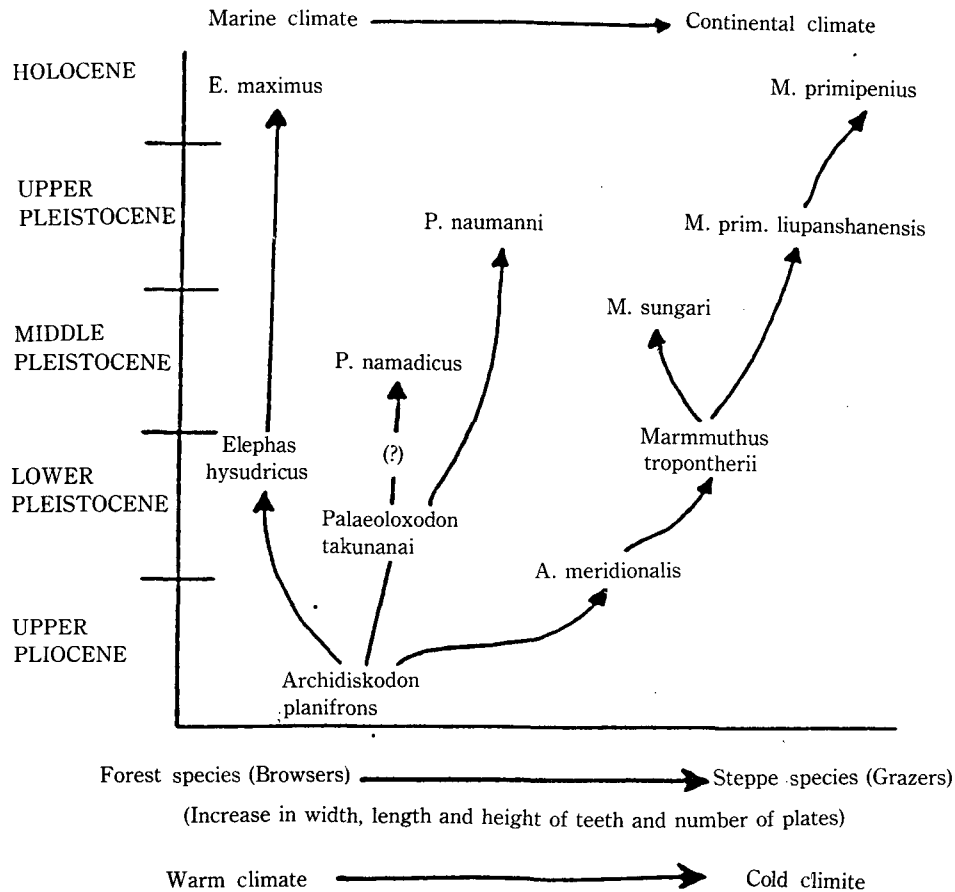


Fig. 5. Chinese Elephantidae (From Zhou and Zhang, 1974)

*namadicus* have been derived separately from the African *E. recki*. Maglio's proposed evolutionary schema is as follows;

This is clearly in contrast to the view of Zhou and Zhang (1974) who see "*Archidiskodon planifrons*" as a basal form for all Chinese elephants (Fig. 5). Maglio does not accept the possibility that *E. namadicus* evolved from an early stage of *M. meridionalis* (the "*A. planifrons*") primarily because *M. meridionalis* is not present during the Villafranchian of Europe. Although *E. namadicus* is not present in Europe until the Cromerian, it may be present much earlier in China (Pope, 1982).

Liu (1977) suggests that *P. naumanni* and *P. takunai* are synonymous and closely related to

European forms of *P. antiquus*. *P. namadicus* has been reported from Nihewan. The specimen is quite similar to *E. namadicus* from Narmada (Wei, 1976). *E. namadicus*, which is the most diversified in the Middle Pleistocene in China, probably survived into the Upper Pleistocene (Wei, 1979).

Mammoth is a representative of the *Mammoth-Coelodonta* fauna of the Upper Pleistocene in Northeast China (Pei, 1957). Maglio suggests that the North American *Mammuthus* was probably derived from a form close to *Mammuthus meridionalis* which entered North America in the late Lower Pleistocene.

According to the study by Zhou Ming-zhen (1974) "The genus *Mammuthus* in China include

*Mammuthus (Parelephas) trogontherii* Pohlig, *Mammuthus (Parelephas) sungari* Chow et Chang, *Mammuthus primigenius* Blumenbach, and one subspecies, *M. primigenius liupanshanensis* Chow et Chang". His suggestion indicates that the *Mammuthus* lineage may be slightly more complicated than the view presented by Maglio.

**B. The Perissodactyla**

The Perissodactyla have been used as "guide fossils" and form one of the best correlations with many other Eurasian faunal localities.

The Equids have been the most widely used guide fossils for the late Cenozoic. The three genera, *Anchitherium*, *Hipparion (sensu lato)* and *Equus (sensu lato)*, appeared in North America first, and migrated to other continents at different times. The temporal overlap of various genera is a potentially useful biochronological marker since in most areas of the Old World this overlap is of short duration (ca 1.0 MYA). An overlap of *Hipparion* and *Equus* has been recorded from several sites in the Old World many of which are radiometrically dated (Eisenmann, 1976; Savage and Curtis, 1970). Based on the appearance of *Equus* in Europe and Eurasia the appearance of *Equus* in China can be no older

than 2.6 MYA (Lindsay *et al.* 1980).

The appearance of *Equus* in various localities in the Old World seems, on the basis of present evidence, to have been a time transgressive phenomenon. In southern China the coexistence of the two genera (*Equus-Hipparion*) has been reported. The two genera known from northern China are probably at least as old as the European forms (Kürten, 1952), and these genera would have lived in sympatric environments. No equid has been reported from the Sunda Shelf.

According to the Liu and You's phylogeny of *Equus* in eastern Asia (1974), *E. yunnanensis* is considered to be the most primitive Chinese *Equus*. They suggest that *E. yunnanensis* shows parallel evolution with a more specialized, and conspecific, Upper Pleistocene form (*E. huiliensis*). Colbert (1940) suggests that *E. yunnanensis* was possibly related to the Upper Pleistocene *E. przewalskii*.

*E. sanmeniensis* has been found strictly in the northern Chinese sites, Nihewan and Zhoukoudian, Locality 1. This form is reported from the Transbaikalian Tolgoy fauna (Vangengeim and Sher, 1970). *E. sanmeniensis* was probably ancestral to one of Upper Pleistocene horses, *E. caballus*.

*E. beijingensis* may be an intermediate form

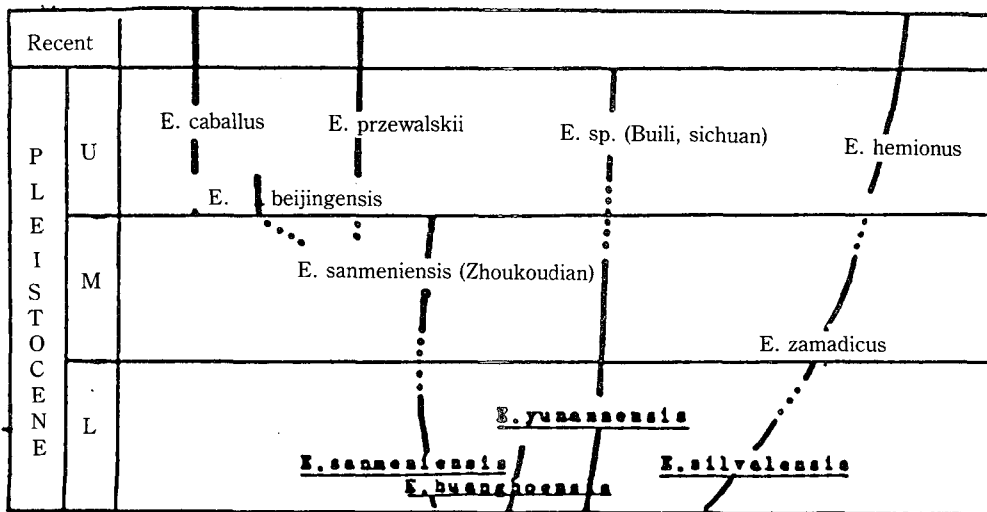


Fig. 6. Phylogeny of *Equus* in Eastern Asia (From Liu and You, 1974)

between *E. sanmeniensis* and *E. przewalskii* on the basis of the comparison of mandibular and cheek teeth morphology (Liu, 1973).

*E. przewalskii* and *E. hemionus* which are typical Upper Pleistocene guide fossils were most likely invading forms whose ancestors occurred outside of China (Liu, 1973).

*E. stenorhinus*, an early Villafranchian form in Europe was probably absent in China during the Pleistocene.

The Rhinocerotidae in the Quaternary of China can be divided into two geographical

forms, northern and southern (Chow, 1979, Table 1). According to Chow's study, *Dicerorhinus yunchuchensis*, *Coelodonta* sp. and *Elasmotherium inexpectatum* are Lower Pleistocene northern forms, while *Rhinoceros sinensis* represents the only Late Pliocene/Lower Pleistocene southern Rhinocerotoid. *Coelodonta antiquitatis* and *D. choukoutiensis* are the typical northern forms.

Chow (1979) provides that the main differences between *D. choukoutiensis* and *D. merckii* are in that the former had an incomplete

**Table 1.** Quaternary Rhinocerotides and Elasmotherium of China (From Chow, 1979)

	Dicerorhinus	Coelodonta	Rhinoceros	Elasmotherium
Holocene	Dicerorhinus sp.? (Southern China, North China)	Szechauc; Chekiang; Kwangsi)	Rhinoceros sp. (Hupei;	
Late Pleistocene	Dicerorhinus sp.? (Southern China)	Coelodonta an- tiquitatis (Blumenbach) (Inner Mongolia; Northeastern China; Northeastern/ Southwest China)	Rhinoceros sp. (Southern China; Central China)	
Middle Pleistocene	Dicerorhinus choukoutiensis Wang (North China)	Coelodonta an- tiquitatis yen- siannensis sub. sp. nov. (North China)	Rhinoceros sin- ensis Owen (Kweichow; Kwangtung; Kwangsi; Szechwan; Hupei; Kiangsu; Chekiang; Taiwan)	Elasmotherium peii Chow (Shansi)
Early Pleistocene	Dicerorhinus yunchuchensis Chow (North China; Shansi)	Coelodonta sp. (North China; Tsinghai)	Rhinoceros sinensis Owen (Kwangsi; Yunan)	Elasmotherium inexpectatum (Shansi)

nasal septum and aspects of occipital morphology. *D. choukoutiensis* was a small steppe form similar to *D. hemitoechus* and *C. antiquitatus* whose extinction occurred in China during the Upper Pleistocene.

In South China, *Rhinoceros sp.* are reported as the Upper Pleistocene rhinocerotoids which are possibly descendants of the Lower and Middle Pleistocene *R. sinensis*.

**C. The Artiodactyla**

A few genera, such as *Leptobos*, *Camelus*, and the cervids may be useful chronostratigraphic markers. It is questionable whether the appearance of *Leptobos* in China can be equated with the early Villafranchian. *Leptobos* fossils are reported from Lantian, but this genus may be referable to a form of *Bison* (Aigner *et al.* 1973). Jia (1980) reports that both *Leptobos* and *Bison palaeosinensis* were found in association with *Hipparion* and *Equus* at Xihoudu, Shanxi.

The first appearance of *Paracamelus* is probably a useful guide for equation with the Villafranchian in Europe (Howell *et al.*, 1969). This genus has been reported with *Equus* in the Late Pliocene and Lower Pleistocene sites of Yushe and Siwalik. Both are known from Middle Pleistocene deposit at Zhoukoudian

(Schlosser, 1928), but the appearance of *Paracamelus (P. gigas)* in the Middle Pleistocene is questionable (Li and Ji, 1981).

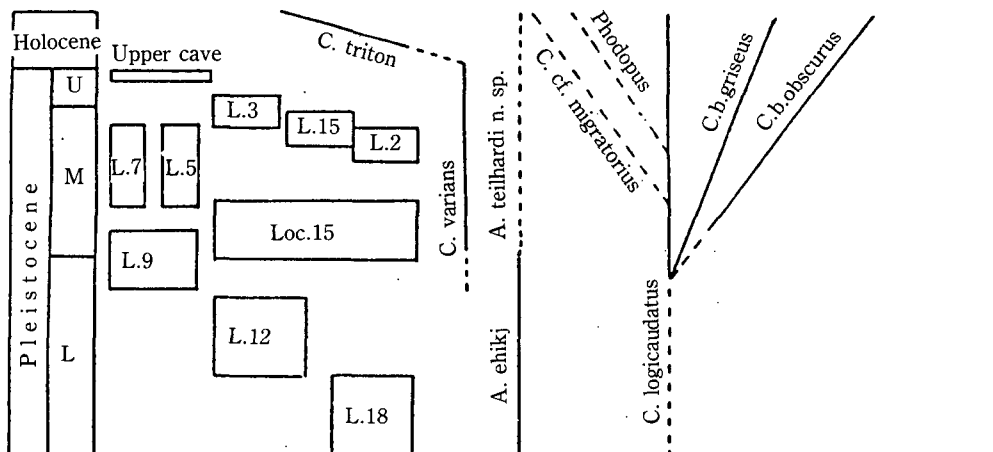
Various cervids have been used to sub-divide the Pliocene and the Pleistocene. *Eucladoceros* has been viewed as a Late Pliocene to Lower Pleistocene form. *Megaloceros pachyosteus* has been considered as a guide fossil for the Middle Pleistocene while *Megaloceros ordosianus* is used for the Upper Pleistocene.

Certain bovids may be somewhat useful as markers during the Villafranchian in Europe, however, no detailed comparison with Plio-Pleistocene forms and little comparison with West Eurasian and African species has been carried out.

**D. The Rodentia**

Rodents have been underrepresented in studies of Chinese faunal assemblages as a result of early collecting techniques. Recently, some rodents (*Cricetinae*, *Myospalax* and *Mimomys*) have been restudied, though the original collections could not be located or might have been lost.

Cricetids have been sporadically used as temporal markers. Zheng *et al.* (1984) re-examines the *cricetinae* from Locality 1, 3, 9, 12, 13, 15



**Fig. 7.** The relative sequence of the main locality of Choukoutien in age and the phylogenetic evolution of Hamsters

and 18 of Zhoukoudian and proposed a relative age sequence for the main Localities of Zhoukoudian. According to his study, *A. ehiki*, the Lower Pleistocene species, might be a transitional form between the Pliocene *Sinocricetus* and the Middle Pleistocene *A. teilhardi sp. nov.*, which probably became extinct at the Upper Cave stage. *C. varians* is closer to the living *C. triton* and can not be on the same phylogenetic line with *Allocricetus*, and perhaps is in close relationship with the Pliocene *Kowalskia*. Another small species, *C. longicaudatus* has retained some primitive features of the Pliocene *Nannocricetus* in its cheek teeth.

*Myospalax* and *Mimomys* have been compared with European assemblages (Zheng 1976; Archaeological United Team, 1976). In the Pleistocene, Chinese rodent assemblages bear a general resemblance to the modern rodents in southwest Asia.

### 3. Chronological Divisions of Pleistocene Mammalian Fauna of China

At present, nearly 200 fossiliferous localities have been reported throughout China. Among them 27 assemblages are taken as representative of the broader range of fossil material (Han, 1985). Small mammalian remains, particularly those from South China, seem to be relatively underrepresented. This may be the result of collecting techniques.

Chronological divisions within the Chinese Pleistocene are conducted through the primary study of mammalian fossiliferous assemblages. Quaternary mammalian faunas in China were subdivided into three chronological units, namely, Early Pleistocene, Middle Pleistocene and Late Pleistocene, each characterized by unique faunal assemblages (Pei, 1957; Kahlke, 1961). At present, it is a general trend to use the chronological terms, Lower and Upper Pleistocene instead of the Early and the Late Pleistocene.

Beginning in the early Quaternary, the faunal composition of the two geographic divisions begin to diverge significantly. Recently, based on the accumulation of new materials, Han (1985) divides China into three faunal zones; North China, South China and a Transitional zone. The following subdivisions will be mainly modified on the basis of Han's study.

#### A. North China

The first Lower Pleistocene *Proboscoidipparion-Equus* (Nihewan) Fauna was found in the lacustrine deposits at Nihewan in the Sangan River valley of northern Hebei. This fauna includes surviving Tertiary fauna such as *Proboscoidipparion sinense*, *Elasmotherium*, *Calicotherium*, and *Machairodus*. Recent forms, such as *Equus*, *Elephas*, *Camelus*, *Bison* and *Ovis* appeared at first in the Lower Pleistocene. Some fauna, *Canis sinensis*, *Paracamelus gigas*, *Cynailurus pleistocaenicus* are found not only at Nihewan but also the Middle Pleistocene fauna at Zhoukoudian Locality 1. As mentioned above, the existence of *Paracamelus gigas* in the Middle Pleistocene remains questionable (Li and Ji, 1981).

The Nihewan Fauna of the Lower Pleistocene developed into the typical *Sinanthropus-Megaloceros pachyosteus* assemblage exemplified by the Middle Pleistocene fossiliferous localities at the type site of Zhoukoudian, Locality 1. Xu (1982) proposes four well known Post-Nihewan faunas of the Lower/Middle Pleistocene in North China on the basis of correlation with deep sea sediments; these are the Dali fauna (*H. sapiens*), Zhoukoudian fauna, Gongwangling, and Chenjiawo faunas.

In the Upper Pleistocene, a new species of hominid and other mammals had formed a vertebrate assemblage essentially similar to that which characterizes the Palaeoartic Realm today. The *Homo sapiens-Megaloceros ordosianus*

Fauna (Sjara-osso-gol Fauna) is a typical Upper Pleistocene fauna. Principal localities include Dali, Shaanxi; Xujiayao, Shanxi; and Sjara-osso-gol (Salawu), and Inner Mongolia. Also, two Upper Pleistocene faunas, Ting-t'sun (Dingcun) and Sjara-osso-gol Fauna are represented (Xu, 1982).

### B. South China

All southern Chinese Pleistocene mammalian faunas may be designated *Ailuropoda-Stegodon* faunas. Han (1985) suggests that the single term "*Gigantopithecus* Fauna of the Lower Pleistocene" proposed by Chow (1957) does not take into account the evolution of various taxa such as *Ailuropoda* and *Tapirus* over a relatively long period of time, and also this term cannot show the essential relationship to the *Ailuropoda-Stegodon* Fauna in the Middle Pleistocene. Instead of the term "*Gigantopithecus* Fauna" in the Lower Pleistocene, Han proposed that all Pleistocene mammalian faunas from South China be referred to collectively as "*Ailuropoda-Stegodon* Faunas", which may be subdivided into discrete temporal stages.

- 1) The Lower Pleistocene Liucheng *Gigantopithecus* Fauna (*Ailuropoda-Stegodon* Fauna, *sensu lato*) is characteristic of South China and exhibits features of the present Oriental Realm. Principal localities include Liucheng, Guangxi, and Jinashi, Hubei. The mammalian fauna represented includes archaic forms of the Pliocene such as Gomphotherium, Chalicotheriidae, small Suidae Cervidae and some new elements of the Lower Quaternary, i.e. *Equus* and a few forms still surviving in the region at the present day such as *Paguma*.
- 2) The *Ailuropoda-Stegodon* Fauna (*sensu stricto*) is a typical Middle Pleistocene Fauna which is more similar in character to that of the modern Oriental Realm, a trend which has continued through the end of the Upper

Pleistocene. Typical assemblages come from the *Gigantopithecus*-bearing localities of Daxin, Wuming, and Bama, all in Guangxi, and Shilongtou, Hubei. This fauna consists of Lower and Middle Pleistocene forms; there are also extinct Pliocene forms and early representatives of modern species.

- 3) Upper Pleistocene *Ailuropoda-Stegodon* Faunas (*sensu lato*) have been found at Maba, Guangdong; Tongzi, Guizhou; and Liujiang, Guangxi. The characteristics of this fauna include numerous Pleistocene forms, but include no archaic species of the Pliocene or special elements of the Lower Pleistocene such as *Ailuropoda microta*, *Crocota licenti*, or *Stegodon preorientalis*.
- 4) Transitional Zone: This poorly defines geographic province in central China, proposed by Han (1985), has yielded Pleistocene fossiliferous assemblages containing elements of both northern and southern faunas. Present evidence shows that the mixed character of this fauna may have begun as early as the Lower Pleistocene. The principal localities are Chaoxian, Anhui (Xu and Fang, 1982); Hexian, Anhui; and Gonwangling and Lantian, Shaanxi.

## THE CURRENT PLEISTOCENE STUDY ON KOREA

Materials for palaeoenvironmental studies in Korea have been found from the caues since the middle of the 1970s (Sohn 1982; Yi 1983). At present the information for palaeoenvironment in Korea are scarce. Consequently, the following assumptions should be considered in reconstructing the palaeoenvironmental conditions of the Pleistocene in Korea:

1. The geomorphology of East Asia including China and Korea during the Pleistocene is similar to that of present day.
2. A comparison of the palaeoclimate between

two places is reasonable if the present, conditions of these two places are comparable.

3. The environmental changes of Korea in the Pleistocene have significantly been influenced by the environmental changes of China. Thus, it would be possible to use the analogy of current Chinese studies for the reconstruction of palaeoecology of Korea.

Although there are accumulation of data at present, as Zhang (1984) pointed out, it is only possible to reconstruct the Upper Pleistocene climate in East Asia quantitatively. The palaeoclimatic indicators possibly used include;

faunal and floral analyses, oxygen isotopic analysis of deep sea sediments, tree-rings and periglacial phenomena. Reliable dating results can have the beneficial effects in the study of palaeoclimates.

At present, studies of the fauna and natural environment of the Pleistocene in Korea remain to be conducted. During the last decade ten

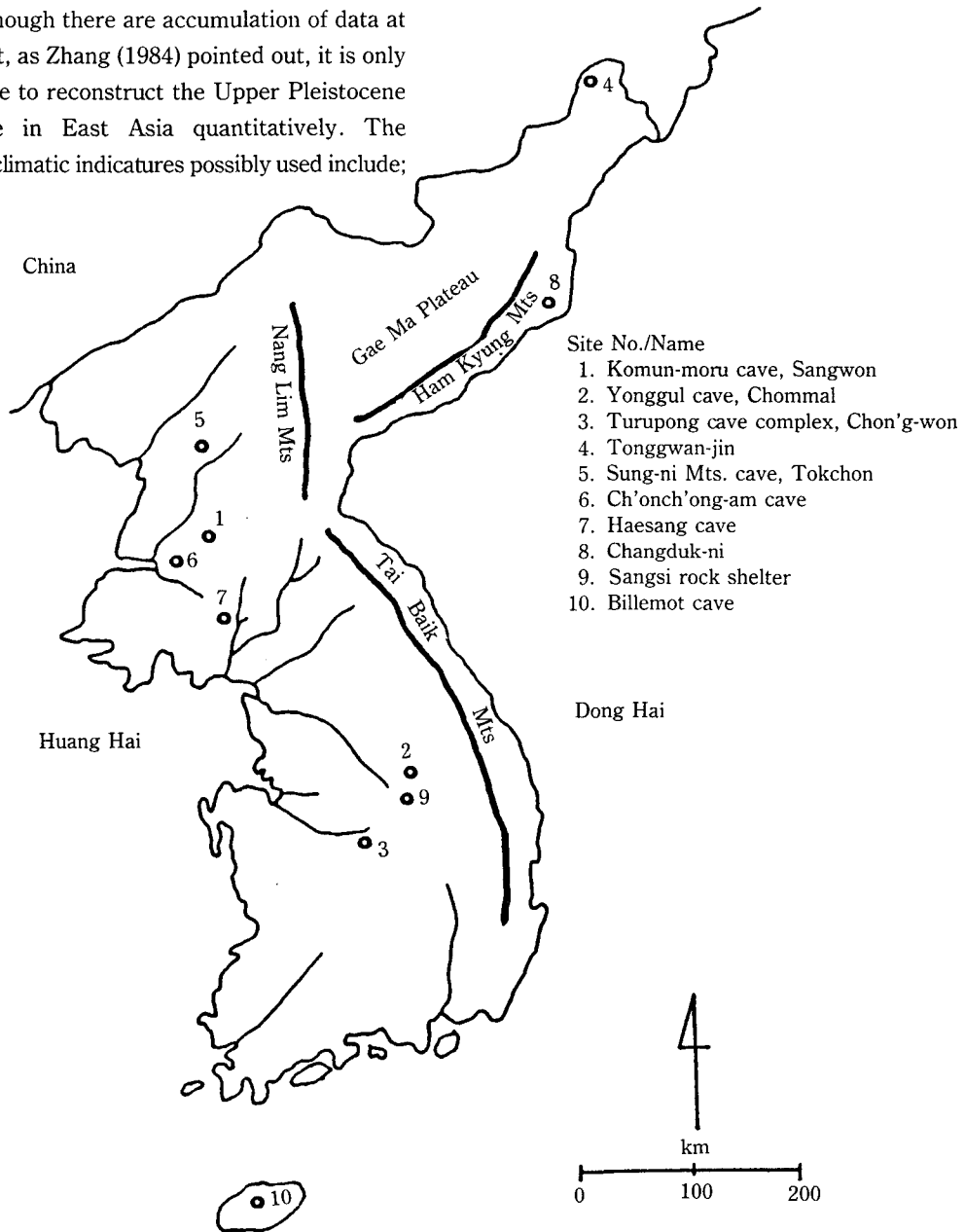


Fig. 8. Sites yielding Middle/Upper Pleistocene fossil mammals in Korea



caves and eight open-sites have been excavated (Fig. 8). A great number of faunal remains (9 orders, 23 families, 53 genera of mammals) have been preliminarily examined (Appendix; B-1). The faunal analysis in Korea basically depends on the Chinese materials. It should be borne in mind that at species level, many names of taxa of Chinese Pleistocene fossil mammals are autonomous. The best way is to compare directly with paleontological and zoological collections.

## CONCLUSION

Palaeoenvironmental studies of East Asia are very important for understanding the way of hominid life in this region during the Pleistocene Period.

The simultaneous upliftings of the Himalayas and the Qinghai/Xizang Plateau were responsible for environmental changes such as the spread of loess and changes in atmospheric circulation in East Asia. Consequently, East Asia is divided into two sections since the Lower Pleistocene: the south tropical zone and the north temperate zone by the Qinling Mountains.

Four different definitions of the Plio-Pleistocene boundary can be provided. Currently, many Chinese geologists have adopted the base of Calabrian stage (1.8mya) as the Plio-Pleistocene boundary in China.

At present, based on the fauna, flora, vegetation and climate, it is more acceptable that zoogeographical provinces of China can be divided into three faunal zones rather than two traditional sections throughout the Pleistocene. Systematic analysis of Chinese mammals have been provided by Chinese scholars. But at the species level, many names are synonymous.

It is assumed that the faunal sequence and natural environment of Korean peninsula have been significantly affected by the environmental changes of continental China since the Late

Tertiary. Faunal dispersal during the Pleistocene may effectively have occurred through the connection between the northeast China and the northern part of Korean peninsula during the several regression of the Huang Hai Sea.

\* **Appendix A:** Fossil Pleistocene Mammals in the North/Northeast China

\* **Appendix B:** Fossil Pleistocene Mammals in Korea

## Appendix A

\* The zoogeography of northern China is subdivided into Northeast China (A) and North China (B).

(Source: From Zhang Yongzu and Zhao Kentung., 1978. On the Zoogeographical Regions of China. *Acta Zoologica Sinica*, 24: 196-202.)

In this paper, the Pleistocene mammals known in fossil form and their localities in North/Northeast China are presented.

## Pleistocene Mammal's Localities of North/Northeast China\*

### I. Principal Localities

#### A. Lower Pleistocene

- L1. Nihewan, Hebei
- L2. Xihoudu Shanxi

#### B. Middle Pleistocene

- M-1. Locality 1 Zhoukoudian, Beijing

#### C. Upper Pleistocene

- U-1. Dali, Shaanxi
- U-2. Locality 100, Dincun, Shanxi
- U-3. Xujiayao, Shanxi
- U-4. Gezidong, Liaoning
- U-5. Sjara-osso-gol (Salawusu), Inner Mongolia Autonomous Region
- U-6. Upper Cave, Zhoukoudian, Beijing

## II. Zoogeographic Subdivisions

### A: Northeast China

Heilongjiang, Jilin and Liaoning

### B: North China

Hebei, Shandong, Shanxi, Shaaxi,  
Southwestern part of Mongol, Southeastern  
part of Gansu, Northern part of Henan and  
Jiansu

	North China	Northeast China
Lower Pleistocene	Nihewan, Hebei	
	Xhihoudu, Hebei	
	Yuxian, Hebei	
	Chiachiashan, Tangshan, Hebei	
	Sanmensia District, Hebei	
	Travertine Cap, Zhoukoudian	
	Beijing	
	Lingyi, Shanxi	
	Tunliu, Shanxi	
	Wensi, Shanxi	
River You, Wenian, Shaanxi		
Puchen, Shaanxi		
Sagou, Miaozueiping, Gansu		
Middle Pleistocene	Locality 1, Zhoukoudian, Beijing	Anping, Liaoyang
	Xiweng Zhung, MiYun, Beijing	Gulongshan, Dalian
	Kehe, Shanxi	Liaoning
	Hei-Mugou, Luochuan, Shaanxi	Jinniushan, Yinkou
	Weixian, Shandong	Liaoning
	Huaiyuan District, Northern part of Gansu	(Middle/Upper Plei.)
	Heshi, Gansu	
	Pingliang, Gansu	
Upper Pleistocene	Upper Cave, Zhoukoudian, Beijing	Chieping, Liaoning
	Yunshui Cave, Beijing	Gezidong, Liaoning
	Hutoulyang, Hebei	Benxi Cave, Liaoning
	Locality 100, Dincan, Shanxi	Xibajianfang, Liaoning
	North China	Northeast China
	Xuijiayao, Shanxi	Antu Cave, Jilin
	Wuzhutai, Xiutai, Shandong	Qingshantou, Jilin
	Qingyang, Gansu	
	Sjara-osso-gol (Salawusu), Inner Mongolia Autonomous Region	

**Appendix A-1:** Distribution of fossil Pleistocene mammals in China

Taxa/Period (Pleistocene)	Lower	Middle	Upper
<b>Primate</b>			
Cercopithecidae			
<i>Macaca robustus</i> Young		M-1,A	B
<i>Macaca</i> sp. indet.		B	
Hominidae			
<i>Homo erectus pekinensis</i> Weidenreich ( <i>Sinanthropus pekinensis</i> Black)		M-1	
<i>Homo sapiens</i> L.			U1,2,3,B
<i>Homo sapiens sapiens</i> L.			U-5,6,A
<b>Insection</b>			
Erinaceidae			
<i>Erinaceus</i> cf. <i>dealbatus</i> Milne-Edwards	L1		
<i>Erinaceus</i> sp. indet.	L2,B		U-4,6
<i>Erinaceus olgai</i> Young		M-1,A	
<i>Erinaceus europaeus</i> L.			U-A
Soricidae			
Soricidae indet.	LB		
<i>Allactaga</i> cf. <i>annulatus</i> Milne-Edwards	L1		
<i>Neomys sinensis</i> Zdansky		M-1	
<i>Neomys bohlini</i> Young		M-1	
<i>Crocidura lasiura</i> Dobson			A
<i>Crocidura</i> sp. indet.		M-1,B	
Talpidae			
<i>Scaptochinrus</i> ( <i>Talpa</i> ) <i>pleistocaenicus</i>		M-1	
<i>Scaptochirus primitivus</i> Zdansky		M-1	
<i>Scaptochirus moschata</i> Milne-Edwards			U-5,A,B
<i>Scaptochirus</i> sp.			U-6
Talpidae gen. et sp. indet.			U-2
<b>Chiroptera</b>			
Rhinolophidae			
<i>Rhinolophus pleistocaenicus</i> Young		M-1	
<i>Rhinolophus</i> sp. indet.			U-6
Vespertilionidae			
<i>Myotis</i> sp. indet.		M-1	
<i>Myotis</i> sp. A,B			U-6
? <i>Heseroptenus giganteus</i> Young		M-1	
? <i>Pipstellus</i> sp. indet.		M-1	
<i>Spermophilus mongolicus</i> (Milne-Edwards)		M-1	
<i>Tamias wimani</i> Young		M-1	
<i>Petaurista brachyodus</i> (Young)		M-1	
<i>Ia io</i>		M-1	
<i>Hipposideros</i> sp.			A

Taxa/Period (Pleistocene)	Lower	Middle	Upper
Vespertilionidae gen. et sp. indet.			U-4
Chiroptera gen. et sp. indet.			U-5,6
Lagomorpha			
Ochotonidae			
Ochotonoides complicitens Boule et Teilhard	L1	B	
Ochotoides sp. indet.	LB		
Ochtona lagrelii minor Bohlin	L1,B		
Ochotona koslowi Buchner		M-1	A
Ochotona thibetana Milne et Edwards		B	
Ochotona hyperborea Pallas		A	
Ochotona sp.indet. A,B		M-1	
Ochotona daurica Pallas			U-4,6,A
Ochotona sp.indet.	LB	B	U-1,3,5
Ochotona cf. manchuricus			A
Leporidae			
Leporidae gen. et sp. indet.	L2		
Hypolagus brachypus		B	
Lepus cf. wongi Yong		M-1,A	
Lepus sp.indet. A,B		M-1	
Lepus sp.indet.	LB	A	U-4,5,A
Lepus europaeus Pallas			U-6
Lepus tolai Pallas			A
Rodentia			
Sciridae			
?Sciurus sp. indet.			U-6
Petaurista sulcatus Howell			U-6
Arctomy robustus Milne-Edwards (Marmota bobok (Radde))		M-1	A
Arctomys (Marmota) omplicitens (Young)		M-1	
Marmota robustus Milne-Edwards			U-4,A
Marmota sp. indet.		M-1	
Spermophilus (Citellus) mongolicus (Milne-Edwards)			U-5,A,B
Spermophilus cf. mongolicus Milne-Edwards	LB	M-1	
Spermophilus sp. indet.	LB		
Citellus sp.			A
Citellus undulatis Pallas			A
Citellus dauricus Brandt			A
Castoridae			
Chalicomys (Castor) anderssoni Schlosser		M-1	
Castoridae gen. et sp. indet.			U-1,2
Trogontherium cf. cuvieri Fischer	LB	M-1	
Trogontherium sp. indet.	L2,B	A,B	
Cricetidae			
Allocricetus ehiki	LB		

Taxa/Period (Pleistocene)	Lower	Middle	Upper
<i>Sinocricetus</i> sp. indet.	LB		
<i>Cricetulus</i> ( <i>Cricetinus</i> ) <i>varians</i> Zdansky		M-1,A	U-6,A,B
<i>Cricetulus</i> cf. <i>griseus</i> Milne-Edwards		M-1	U-5
<i>Cricetulus</i> cf. <i>obscurus</i> Milne-Edwards		M-1	U-6
<i>Cricetulus</i> <i>barabensis</i> Pallas			A
<i>Cricetulus</i> <i>triton</i> De Winton et Styan			A
<i>Cricetulus</i> sp. indet.	LB		U-4,5,A,B
<i>Gerbillus</i> <i>roborowskii</i> Buchner		M-1	
<i>Gerbillus</i> ( <i>Meriones</i> ) <i>meridianus</i> Pallas			U-5
<i>Gerbillus</i> sp. indet.		B	U-5
<i>Clethrionomys</i> ( <i>Evotomys</i> ) <i>rufocanus</i> Sundvell		M-1	
? <i>Eothenomys</i> sp. indet.		M-1	U-5
? <i>Phaiomys</i> sp. indet.		M-1	
<i>Pitymys</i> <i>simplicidens</i> Young		M-1	
<i>Epimys</i> sp. indet.	LB		
<i>Microtus</i> <i>epiraticiceps</i> Young		M-1,A	U-4
<i>Microtus</i> <i>brandtoides</i> Young	L1	M-1	U-3,B
<i>Microtus</i> cf. <i>ratticeps</i> Keyserling et Blasius			U-5
<i>Microtus</i> sp. indet.	LB		A
Microtinae sp. indet.		B	
<i>Myospalax</i> <i>tingi</i> Young	L1		
<i>Myospalax</i> cf. <i>tingi</i> Young	LB		
<i>Myospalax</i> <i>wongi</i> (Young)		M-1	
<i>Myospalax</i> <i>epitingi</i> Teilhard et Pei		M-1	
<i>Myospalax</i> <i>arvicolinus</i> Nehring		B	
<i>Myospalax</i> sp. indet.		M-1	U-4,A
<i>Myospalax</i> cf. <i>epsilanus</i> Milne-Edwards			A
<i>Myospalax</i> <i>epsilanus</i> Milne-Edwards		A	A
<i>Myospalax</i> cf. <i>psilanus</i> Milne-Edwards			A
<i>Myospalax</i> <i>psilanus</i> Milne-Edwards		B	A
<i>Myospalax</i> <i>chaoyatseni</i> Teilhard et Young	LB	B	
<i>Myospalax</i> <i>hsuchiaponensis</i> Teilhard et Young	LB	B	
<i>Siphneus</i> ( <i>Myospalax</i> ) <i>fontanieri</i> (Milne-Edwards)		A	U-2,3,5,A,B
<i>Siphneus</i> ( <i>Myospalax</i> ) <i>armandi</i> Milne-Edwards			U-6,A
<i>Prosiphneus</i> <i>youngi</i> Young	LB		
<i>Prosiphneus</i> cf. <i>intermedius</i> Teilhard et Young	LB		
<i>Prosiphneus</i> sp. indet.	LB		
<i>Miomys</i> sp. indet.	LB		
<i>Miomys</i> <i>gansunicus</i> sp. nov.		B	
<i>Miomys</i> cf. <i>branchiaonicus</i>	LB		
<i>Arvicola</i> <i>terrae-rubrae</i> Teilhard	LB		
<i>Arvicola</i> gen. et sp. indet.	L1		
<i>Alticola</i> sp. indet.		M-1	
<i>Alticola</i> cf. <i>aricetulus</i> Miller			U-5
<i>Alticola</i> cf. <i>stracheyi</i> Thomas			U-6,B

Taxa/Period (Pleistocene)	Lower	Middle	Upper
<b>Dipodidae</b>			
? <i>Smithoides fraudator</i> Schlosser		B	
<i>Dipus sowerbyi</i> Thomas			U-5
<i>Allataga cf. annulatus</i> Milne-Edwards			U-5
<i>Allataga sibirica</i> Foster			A
<b>Muridae</b>			
<i>Orientalomys nihowanicus</i> sp. nov (Tang)	L1,B		
<i>Micromys cf. minutes</i> Pallas		M-1	
<i>Mus rattus</i> L.	LB		
<i>Mus musculus bieni</i> Young		M-1	
<i>Mus musculus</i> L.			A
<i>Mus (Apodemus) sylvaticus</i> L.		M-1,B	U-6
<i>Mus</i> sp. indet.	LB		
<i>Rattus rattus</i> L.		M-1	U-4,6,A,B
<i>Rattus</i> sp.			A
Muridae gen. et sp. indet.			U-2
<b>Rhizomyidae</b>			
<i>Rhizomys</i> sp.indet.		M-1	
<b>Hystriidae</b>			
<i>Hystrix cf. subcristata</i> Swinhoe		M-1	
<i>Hystrix lagrelii</i> Lonnberg	LB	A	A
<i>Hystrix</i> sp. indet.	LB		
<b>Carnivora</b>			
<b>Canidae</b>			
<i>Canis chiliensis</i> Zdansky	L1		A
<i>Canis cf. chiliensis</i> Zdansky			U-4
<i>Canis chiliensis palmidens</i> Teilhard et Piveteau	L1		
<i>Canis chiliensis minor</i> Teilhard et Piveteau	L1,B		
<i>Canis lupus</i> L.		M-1	U-3,5,A,B
<i>Canis lupus variabilis</i> Pei	LB	M-1,A,B	A
<i>Canis cyonoides</i> Pei		M-1	
<i>Canis</i> sp. indet.	LB	A,B	U-2
<i>Canis familiaris</i>			A
<i>Nyctereutes sinensis</i> Schlosser	L1,B	M-1,A	
<i>Nyctereutes cf. sinensis</i> Schlosser	LB		
<i>Nyctereutes cf. procyonoides</i> (Gray)			U-2,6,A
<i>Nyctereutes procyonoides</i> Gray			B
<i>Nyctereutes</i> sp.			A
<i>Vulpes</i> sp.indet.	L1,B		U-2
<i>Vulpes cf vulpes</i> L.		M-1	
<i>Vulpes cf. corsac</i> L.		M-1,A	U-4,A
<i>Vulpes corsac</i> L.			U-6,A
<i>Vulpes cf. vulgaris</i> L.		M-1	
<i>Vulpes vulgaris</i> L.			U-6
<i>Vulpes cf.chiliensis</i>			U-A

Taxa/Period (Pleistocene)	Lower	Middle	Upper
<i>Ouon</i> cf. <i>alpinus</i> Pallas		M-1	A
<i>Ouon alpinus</i>			U-6
<i>Ouon alpinus</i> var. <i>antiqua</i> Milne-Edwards		A	
<i>Ouon antiquus</i> Matthew et Granger		M-1	
<i>Ouon</i> sp. indet.			A
Canidae gen. et. sp. indet.		M-1	
Ursidae			
<i>Ursus</i> cf. <i>etruscus</i> Ouvier	L1		
<i>Ursus augustidens</i> Zdansky ( <i>ursus thibetanus kokeni</i> Matthew et Granger)		M-1	U-6
<i>Ursus thibetanus</i> cuvier		B	
<i>Ursus arctos</i> L.		M-1,A	U-A
<i>Ursus spelaeus</i> Rosenmuller et Heinroth		M-1	U-6
<i>Ursus</i> cf. <i>spelaeus</i> Rosenmuller et Heinroth		M-1	
<i>Ursus</i> sp. indet.	LB		U-2,A
? <i>Ailuropoda</i> sp. indet.		M-1	
Mustelidae			
<i>Mustela pachygnatha</i> Teilhard et Piveteau	L1		
<i>Mustela</i> cf. <i>altaica</i> Pallas			U-6
<i>Mustela constricta</i> Teilhard et Pei		B	
<i>Mustela nivalis</i> L.		M-1	
<i>Mustela</i> ( <i>Putoria</i> ) <i>eversmanni</i> Hollister			U-6,A
<i>Mustela</i> ( <i>Putoria</i> ) cf. <i>sibirica</i> Pallas		M-1,A	U-A
<i>Mustela</i> ( <i>Putoria</i> ) sp. indet.	LB		
<i>Mustela</i> sp. indet.			A,B
<i>Paguma larvata</i> (Hamilton-Smith)			U-6,B
<i>Meles chiai</i> Teilhard	LB		
<i>Meles</i> cf. <i>leucurus</i> Hodgson	L1	M-1,A,B	A
<i>Meles leucurus</i> Hodgson		A	U-6,B
<i>Meles taxus</i> Boddaert			U-5
<i>Meles</i> cf. <i>meles leptopynehus</i> Milne-Edwards			A
<i>Meles meles</i> L.		B	U-5
<i>Lutra licenti</i> Teilhard et Piveteau	L1		
<i>Lutra</i> cf. <i>licenti</i> Teilhard et Piveteau	LB		
<i>Lutra melina</i> Pei		M-1	
<i>Lutra</i> sp.			A
<i>Qulo</i> sp. indet.		M-1	
<i>Martes</i> sp. indet.		M-1	
Hyaenidae			
<i>Hyaena brevirostris licenti</i> Pei	L1		
<i>Hyaena brevirostris sinensis</i> Owen		M-1	
<i>Hayena</i> sp. indet.	L1,2,B	M-1	A
<i>Crocota crocuta ultima</i> (Matsumoto)		M-1	U-4,5,6,A,B
Felidae			

Taxa/Period (Pleistocene)	Lower	Middle	Upper
Megatherion ( <i>Machairodus</i> ) <i>nihowanensis</i> Teilhard et Piveteau	L1,B		
Megatherion <i>inexpectatus</i> Teilhard		M-1	
Megatherion sp. <i>indet.</i>	LB		
<i>Homotherium ultima</i>			A?
<i>Felis</i> sp. <i>indet.</i>	L1,B	M-1	U-4,B
<i>Felis</i> ( <i>Panthera</i> ) <i>tigris</i> L. (Leo:Savage)		M-1,A	U-3,5,6,A,B
<i>Felis</i> cf. <i>pardus</i> L. (Leo:Savage)		M-1	U-6
<i>Felis youngi</i>		M-1,A	
<i>Felis teilhardi</i> Pei		M-1,B	
<i>Felis</i> cf. <i>microtus</i> Milne-Edwards		M-1	U-4,6,A
<i>Lynx</i> sp. <i>indet.</i>	L1		U-4,6,A
<i>Lynx variabilis</i> sp. <i>nov.</i> (Tang)	LB		
<i>Lynx lynx</i> L.			U-6
<i>Felis catus</i> L.			U-6
<i>Felis chihliensis</i>			A
<i>Cynailurus</i> ( <i>Acinonyx</i> ) cf. <i>pleistocennicus</i> Zdansky	L1		
<i>Cynailurus</i> sp. <i>indet.</i>		M-1,B	A
<i>Cynailurus</i> cf. <i>jubatus</i> Walger			U-6
Viverridae			
<i>Viverra peii</i> sp. <i>nov.</i>	LB		
Proboscidae			
Elephantidae			
<i>Palaeoloxodon namadicus</i> Falconer et Cautley	L1,B	M-1,B	U-2,B
<i>Palaeoloxodon tokunagai</i> Matsumoto	LB		
<i>Palaeoloxodon</i> cf. <i>tokunagai</i> Matsumoto			U-2
<i>Palaeoloxodon pingliangensis</i> sp. <i>nov.</i>		B	
<i>Palaeoloxodon</i> sp. <i>indet.</i>			U-1
<i>Palaeoloxodon naumanni hawaiiensis</i> subsp. <i>nov.</i>		B	
<i>Palaeoloxodon</i> cf. <i>naumanni</i> Makiyama			U-3
<i>Elephas meridionalis</i>	LB		
<i>Elephas youheensis</i> sp. <i>nov.</i>	LB		
<i>Elephas</i> cf. <i>namadicus</i> Falconer et Cautley	L2		U-5
<i>Elephas</i> cf. <i>indicus</i> L.			U-2
<i>Elephas</i> sp. <i>indet.</i>	LB		U-6
<i>Archidiscodon planifrons</i> Falconer et Cautley	L2		
<i>Archidiscodon weifangensis</i> sp. <i>nov.</i>		B	
<i>Archidiscodon</i> sp. <i>indet.</i>	LB	B	
<i>Mammuthus primigenius</i> Blumenbach			A
<i>Mammuthus</i> ( <i>Parelephas</i> ) <i>sungari</i> Chow et Chang			A
Stegodontidae			
<i>Stegodon</i> Zdansky	LB		
<i>Stegodon</i> cf. <i>chiai</i>	LB		
<i>Stegodon</i> sp. <i>indet.</i>	L2		
<i>Stegodon</i> cf. <i>orientalis</i> Owen		B	



Taxa/Period (Pleistocene)	Lower	Middle	Upper
Perissodactyla			
Equidae			
<i>Hipparion</i> ( <i>Proboscidea</i> ) <i>sinense</i> Sefve	L1,2,B		
<i>Hipparion</i> sp. indet.	LB		
<i>Hipparion</i> <i>houfenense</i> Teilhard et Young	LB		
<i>Hipparion</i> cf. <i>houfenense</i>	LB		
<i>Equus</i> <i>sanmeniensis</i> Teilhard et Piveteau	L1,2,B	M-1,A	
<i>Equus</i> cf. <i>sanmeniensis</i> Teilhard et Piveteau	LB	B	
<i>Equus</i> <i>huanghoensis</i> Chow et Liu	LB		
<i>Equus</i> <i>beijingensis</i> sp. nov.		M-1	
<i>Equus</i> <i>hemionus</i> Pallas		B	U-2,3,5,6,A,B
<i>Equus</i> cf. <i>hemionus</i> Pallas			U-4
<i>Equus</i> <i>przewalskyi</i> Poliakov			U-2,3,A,B
<i>Equus</i> cf. <i>przewalskyi</i> Poliakov		B	U-5
<i>Equus</i> <i>dalianensis</i> sp. nov.		B	
<i>Equus</i> <i>caballus</i>			A
<i>Equus</i> sp. indet.			U-1,4,A,B
<i>Asianus</i> sp.			A
Rhinocerotidae			
<i>Rhinoceros</i> cf. <i>sinensis</i> Owen	L1		
<i>Rhinocerotides</i>	LB	M-1	
<i>Rhinoceros</i> sp. indet.			U-1,6
<i>Dicerorhinus</i> sp. indet.	LB	B	
<i>Dicerorhinus</i> <i>yunchucuchenensis</i> sp. nov.	LB		
<i>Dicerorhinus</i> <i>chokoutiensis</i> Wang		M-1	
<i>Dicerorhinus</i> <i>merki</i> Jaeger	LB	M-1,A,B	U-2,A
<i>Dicerorhinus</i> cf. <i>kirchbergensis</i> Jaeger		M-1	
<i>Coelodonta</i> <i>antiquitatis</i> Blumenbach	L1,B	A,B	U-2,3,4,5,A,B
<i>Coelodonta</i> <i>antiquitatis</i> <i>yenshanensis</i> Chow		M-1	
<i>Coelodonta</i> <i>antiquitatis</i> <i>chilhlinesis</i> subsp. nov.			A
<i>Coelodonta</i> sp. indet.		B	
<i>Elathmotherium</i> sp. indet.	L1		
<i>Elathmotherium</i> <i>peii</i>	LB		
<i>Elathmotherium</i> cf. <i>inexpectatum</i> Chow	L2		
<i>Cirocotherium</i> sp. indet.	L1		
Chalicotheriidae			
<i>Chalicotherium</i> gen. et sp. indet.	L1		
Artiodactyla			
Suidae			
<i>Suidae</i> indet.	LB		
<i>Sus</i> <i>subtriquetra</i> sp. nov.	LB		
<i>Sus</i> <i>lydekkeri</i> Zdansky		B	
<i>Sus</i> cf. <i>lydekkeri</i> Zdansky	L1,2	M-1,B	
<i>Sus</i> sp. indet.	LB		U-2,3,6,B
<i>Sus</i> <i>scrofa</i> L.		A	U-5.A.B

Taxa/Period (Pleistocene)	Lower	Middle	Upper
Camelidae			
<i>Camelus</i> ( <i>Paracamelus</i> ) <i>gigas</i> Schlosser	L1	M-1?	
<i>Camelus</i> ( <i>Paracamelus</i> ) sp. indet.	LB		
<i>Camelus knoblochi</i> Brandt			U-5
<i>Palaeotrgus progressus</i> sp. nov.	LB		
Cervidae			
<i>Cervus</i> cf. <i>sinensis</i> Teilhard et Piveteau	L1		
<i>Cervus</i> ( <i>Elaphurus</i> ) <i>bifurcatus</i> Teilhard Piveteau	L1,2,B		
<i>Cervus</i> cf. <i>bifurcatus</i> Teilhard et Piveteau	LB		
<i>Cervus</i> ( <i>Elaphurus</i> ) <i>chinnaniensis</i> Chia et Wang	L2,B		
<i>Cervus</i> ( <i>Eucladocerus</i> ) <i>boulei</i> Teilhard et Piveteau	L1,2		
<i>Cervus</i> cf. <i>boulei</i> Teilhard et Piveteau	LB		
<i>Cervus</i> ( <i>Rusa</i> ) <i>elegans</i> Teilhard et Piveteau	L1,B	A	
<i>Cervus</i> cf. <i>elegans</i> Teilhard et Piveteau	LB		
<i>Cervus</i> ( <i>Rusa</i> ) sp. indet.	L1		
<i>Cervus</i> sp. indet.	LB	M-1,b	U-4,A,B
<i>Cervinae</i> gen. et sp. indet.	L2		
<i>Cervus elaphus</i> L.		M-1	U-3,5,B
<i>Cervus nippon grayi</i> Temninca			U-3
<i>Cervus grayi</i>		M-1	A
<i>Cervus mongoliae</i> Gaudry			U-5
<i>Cervus</i> cf. <i>mongolicus</i> Gaudry			A
<i>Elaphus canadensis asiaticus</i> Lydekker			A
<i>Cervus canadensis</i> Erxleben ( <i>Elaphus canadensis</i> Severtzow)			U-6,A
<i>Cervus xanthopygus</i> Milne-Edwards		A	A
<i>Cervus manchuricus</i> L.			A
<i>Euctenoceros boulei</i> Teilhard et Piveteau	LB		
<i>Euctenoceros</i> cf. <i>tetraceros</i> (Dawkins)	LB		
<i>Euctenoceros</i> sp. indet.	LB		
<i>Munitiacus</i> sp.			A
<i>Axis rugosus</i> Chow	L2,B		
<i>Axis</i> cf. <i>rogosus</i> Chow	LB		
<i>Axis shansius</i> Teilhard et Piveteau	L2,B		
? <i>Hydropotes</i> sp. indet.		M-1,A	A
<i>Moschus moschiferus pekinensis</i> Young		M-1	A
<i>Moschus moschiferus variation</i> Young		A	
<i>Moschus</i> sp. indet.	LB		U-2,A
<i>Capreolus</i> sp. indet.		M-1,A,B	U-A
<i>Capreolus manchuricus</i> Noack			U-6,A
<i>Capreolus</i> cf. <i>manchuricus</i> Lydekker		A	A
<i>Procapra picticaudata przewalkii</i>			B
<i>Euryceros pachyosteus</i>		B	
<i>Euryceros flabellatus</i>		B	
<i>Pseudaxis grayi</i> Zdansky		M-1,A	

Taxa/Period (Pleistocene)	Lower	Middle	Upper
<i>Pseudaxis cf. gray</i> Zdansky			U-1,2
<i>Pseudaxis hortulorum</i> Swinhoe			U-6
<i>Pseudaxis cf. nayaur</i>			A
<i>Pseudaxis sp.</i>		B	A
<i>Alces alces</i>			A
<i>Megaloceros pachyosteus</i> Young		M-1,A,B	U-1
<i>Megaloceros flabellatus</i>		B	
<i>Megaloceros luochuanensis sp. nov.</i>		B	
<i>Megaloceros sangganhoensis</i>		B or	B
<i>Megaloceros ordosianus</i> Young			U-2,3,5,A,B
<i>Megaloceros sp. indet.</i>		A	U-1,2
<b>Bovidae</b>			
<i>Gazella sinensis</i> Teilhard et Piveteau	LB		
<i>Gazella cf. blacki</i> Teilhard et Piveteau	L2,B		
<i>Gazella cf. subgutturosa</i> Guldenstaedt	L1		
<i>Gazella subgutturosa</i> Guldenstaedt			U-3,5,B
<i>Gazella sp. indet.</i>	LB	M-1,A,B	U-2,3,4,A
<i>Gazella przewalskyi</i> Buchner			U-5,6,A
<i>Pseudois nayaur</i> Hodgson		B	
<i>Pseudois cf. nayaur</i> Hodgson			U-4
Antilopinae gen. et sp. indet.	L1		
<i>Antiospira yusianensis sp. nov.</i> (Tang)	LB		
<i>Spiroceros wongi</i> Teilhard et Piveteau	L1		
<i>Spiroceros cf. wongi</i> Teilhard		M-1	
<i>Spiroceros peii</i> Young		M-1	U-3
<i>Spiroceros hsuchiayaocus</i> Jia, Wei et Li			U-3
<i>Spiroceros sp. indet.</i>			U-2,B
<i>Spiroceros kiakhtensis</i> Pavlov			U-5,A
<i>Procapra pitecaudata przewalskyi</i> Buchner			U-3
<i>Ovis shantungensis</i> Matsumoto	L1		
<i>Ovis cf. ammon</i> Pallas		M-1	
<i>Ovis among</i> Pallas			U-5,A,B
<i>Ovis sp. indet.</i>		M-1	U-6
Ovibovinae gen. et sp. indet.	L1	M-1	
<i>Bison palaeosinensis</i> Teilhard et Piveteau	L1,2		
<i>Bison cf. palaeosinensis</i> Teilhard et Piveteau	LB		
<i>Bison sp. indet.</i>	LB	M-1,A,B	
<i>Bison harbinensis</i>			A
<i>Bison exiguus</i> Matsumoto			A
<i>Bison exiguus exiguus</i>			A
<i>Bison exiguus curvicornis</i>			A
<i>Bison priscus</i> Bojanus			A
<i>Leptobos crauss? Jia et Wang</i>	L2,B		
<i>Bos primigenius</i> Bojanus		B	U-2,3,5,A,B
<i>Bos primigenius</i> subsp.			A

Taxa/Period (Pleistocene)	Lower	Middle	Upper
<i>Bos taurus</i>			A
<i>Bos sp. indet.</i>		B	U-4,6,A,B
Bovinae Gray	LB	B	A
<i>Bubalus teilhard</i> Young		M-1	
<i>Bubalus sp. indet.</i>		B	U-1,2,B
<i>Bubalus wansjocki</i> Boule et Teilhard			U-5,A

**Appendix B-1:** Distribution of fossil Pleistocene mammals in Korea

	Site: 1	2	3	4	5	6	7	8	9	10
Artiodactyla										
<i>Sus scrofa</i> L.	X		X		X	X	X			
<i>Sus sp.</i>			X							
<i>Cervus elaphus</i> L.	X		X	X	X		X			X
<i>C. e. canadiensis</i> Erxleben				X						
<i>Cervus sp.</i>		X	X		X				X	
<i>Cervus nippon</i>					X	X	X			
<i>Capreolus capreolus</i> L.		X	X		X	X	X		X	X
<i>Hydropotes inermis</i> Swinhoe						X	X			
<i>C. cf. pygargus ochracea</i>				X						
<i>Moschus moschiferus</i> L.		X	X							
* <i>Pseudaxi grayi</i> Zdansky	X		X						X	
* <i>Pseudaxis grayi</i> var. Zdansky			X							
* <i>Megaloceros flabellatus</i> Teilhard et Pei	X									
* <i>Megaloceros sangwonensis</i> Kim singiu	X									
* <i>Megaceros sp.</i>				X	X					
* <i>Bos primigenus</i> Bojanus	X		X	X	X					
* <i>Bison exguus</i> Matsumoto				X						
* <i>Bison priscus</i> Bojanus		X		X						
* <i>Ovis cf. ammon</i> L.				X						
* <i>Bubalus sp.</i>	X				X					
<i>Naemorhedus goral</i> Hardwake					X	X	X			
Perissodactyla										
<i>Equus sp.</i>	X	X								
* <i>Equus caballus</i> L.					X				X	
* <i>Equus sangwonensis</i> K. giogen	X									
* <i>Dicerrhinus kirchbergensis</i> Jager	X		X		X					
* <i>Coelodonta antiquitatis</i> Blumenbach		X		X						
Carnivora										
<i>Meles meles</i> L.	X	X					X			
<i>Meles sp.</i>			X							
<i>Lutra lutra</i> L.		X		X						



(Cont')	Site	1	2	3	4	5	6	7	8	9	10
* <i>Alloricetus bursae correzensis</i>				X							
* <i>Miomys</i> sp.		X									
* <i>Pitymys simplicidens</i> Young		X									
<i>Apodemus sylvaticus</i> L.		X	X								
<i>Apodemus</i> sp.				X							
<i>Rattus rattus</i> L.		X		X							
* <i>Castor</i> sp.		X									
* <i>Castor fiber</i> L.						X					
* <i>Myospalax</i> cf. <i>epitimgi</i> Teilhard et Pei		X									
* <i>Myospalax</i> cf. <i>epsilanus</i> Thomas					X						
* <i>Siphneus</i> sp. cf. <i>wongi</i> Insectivora				X							
<i>Talpa</i> sp.			X	X							
Erinaceous sp.			X	X							
<i>Sorex</i> sp.			X	X							
<i>Crocidura</i> sp.				X							
Chiroptera											
<i>Rhinolophus ferrum-equinum</i>			X	X							
<i>Myotis nattereri amurensis</i>				X							
<i>Plecotus auritus</i>			X	X							
<i>Plecotus</i> sp.				X							
<i>Nyctalus</i> cf. <i>Lesileri</i>				X							
<i>Miniopterus schreibersii</i>			X								
<i>Murina leucogaster</i>			X	X							
* <i>Lasionycteris noctivagans</i> Primates				X							
* <i>Macaca</i> sp. cf. <i>robustus</i>		X	X								
* <i>Macaca robustus</i> Young				X							
* <i>Macaca</i> sp.		X									
<i>Homo sapiens</i>						X				X	

## \* Site

- |  |                                |
|--|--------------------------------|
| 1. Komun moru Cave, Sangwon                  | 6. Chongchong-am Cave, Sangwon |
| 2. Yonggul, Chommal                          | 7. Haesang Cave, Pyungsan      |
| 3. Turupong Cave Complex (#2, 9), Cho'ng-won | 8. Changduk-ni                 |
| 4. Tonggwan-jin                              | 9. Sangsi-ri Cave              |
| 5. Sung-ni Mt. Cave, Tockchon                | 10. Bilemot Cave               |

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