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# 1. The Fossils of the Przewalski's horse and the climatic variations of the Late Pleistocene in China

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*Fossils of the Przewalski's horse were discovered widespread in a lot of the Late Pleistocene faunas and the Paleolithic sites in northern China. The ecological environment of the extant Przewalski's horse proves that it exists in the winter monsoon region, and adapts to dry and cold climate. During the stage of strong summer monsoon in the Late Pleistocene, the Przewalski's horse was absent in northern China. During strong winter monsoon, on the other hand, it appeared frequently among the mammalian faunas in this region. An analysis on the enamel carbon isotope of the Przewalski's horse indicates that $C_3$ grass was dominant in the habitats of the Przewalski's horse in northern China during the Late Pleistocene. The geological distribution of the Przewalski's horse was related to the temporal and spatial variation of the East-Asian monsoon. The distribution of the Przewalski's horse in northern China can sensitively reflect the variation of the East-Asian monsoon. As a result, the fossils of the Przewalski's horse can be regarded as an indicator of the climatic variation in northern China since the Late Pleistocene.*

## Introduction

The Przewalski's horse (*Equus przewalskii*) distributed widely in the Late Pleistocene of China, and its fossils are discovered from many Late Pleistocene mammalian faunas and Paleolithic sites, with a vast range from western Xinjiang (Jin 1991) as far as the Taiwan Channel (Gao 1982). On the other hand, the extant Przewalski's horse is a kind of animal on the brink of extinction, with a narrow distribution limited to northern Xinjiang of China and the Kobdo Basin of Mongolia (Fig. 1). What factors control the distribution of the Przewalski's horse? Is it relevant to the variation of the Late Pleistocene? These problems will be discussed in this paper.

### *Ecological characteristics of the Przewalski's horse*

The natural habitat of the Przewalski's horse is semi-desert, at some 1000 to 1400 meters altitude (Groves 1994). The habit of Przewalski's horses shows their adaptation for the arid environment: they gather as a herd with vagrant behavior in spring and summer; they seem to keep to the saline steppes and are able to survive a long time without water; they frequently use fore feet to dig small pits in low-lying place where salty water accumulates for drinking; their main diet is composed of desert vegetation such as *Haloxylon ammodendron*, *Artemisia incana*, *Salicornia herbacea*, *Equisetum*, *Scorzonera*, *Phragmites*, and *Salsola*; they satisfy their thirst with snow, and look for dry grass and lichen to alley their hunger in winter. Foals of Przewalski's horses are very afraid crossing rivers, obviously, which is an impression from their ancestor for a long-term life in arid regions. The Przewalski's horse has an astonishing running ability, which also is an adaptation to the semi-desert habitats (Cui 1962).

When Przewalski's horses were discovered in the 19th century, their distribution area was Dzungaria basin and Manas river valley by the south of Altai and the north of Tianshan mountains, and extended eastwards to Bajtag-Bogdo Mountain along Urungu river as well as to the Kobdo basin in Mongolia (Allen 1940). Since a filly of the Przewalski's horse in the wild was captured in 1947, any assured evidence has not been found in natural environment. It seems, therefore, that the Przewalski's

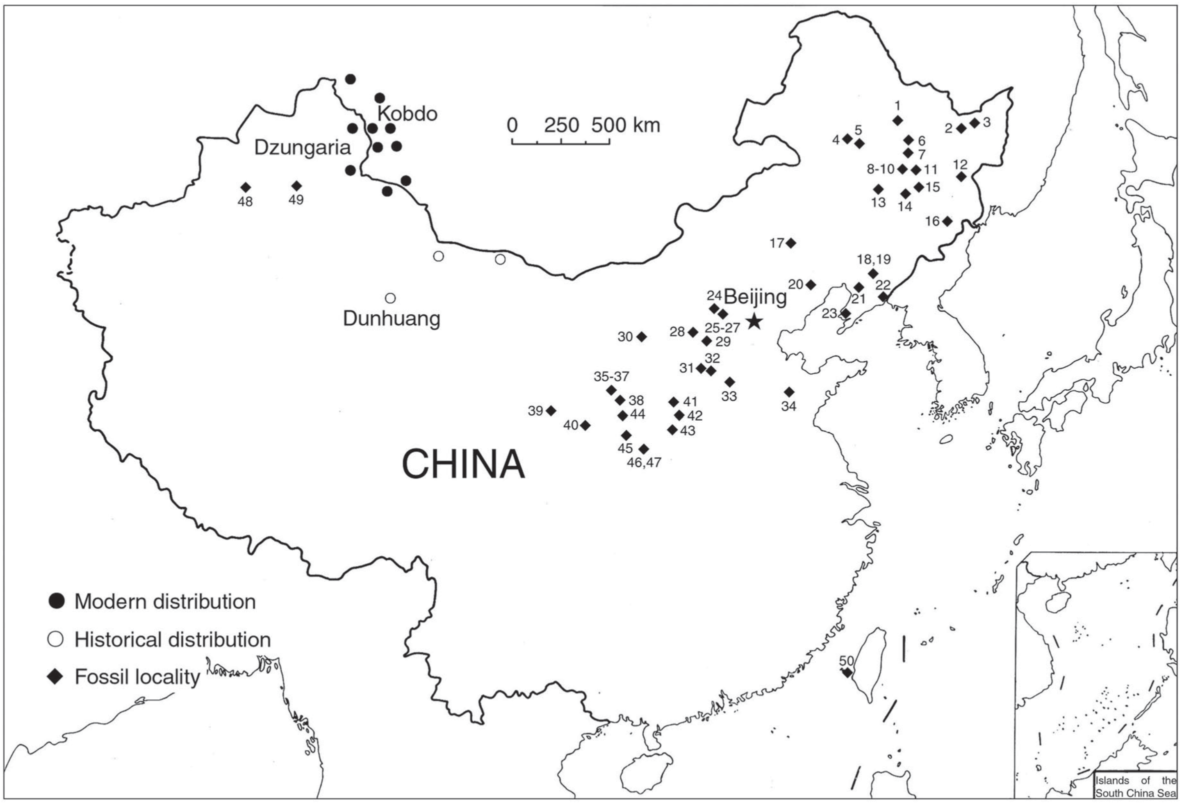


*Fig. 1. Distributions and localities of the Przewalski's horse. 1. Beian, 2. Jixian, 3. Fujin, 4. Nianzishan, 5. Angangxi, 6. Suileng, 7. Suihua, 8. Yanjiagang, 9. Guxiangtun, 10. Huangshan, 11. Binxian, 12. Muleng, 13. Qingshantou, 14. Yushu, 15. Xuetian, 16. Shimenshan, 17. Wurji, 18. Shanchengzi, 19. Benxihu, 20. Gezidong, 21. Xiaogushan, 22. Qianyang, 23. Gulongshan, 24. Xujiayao, 25. Shenquansi, 26. Hutouliang, 27. Xibaimaying, 28. Shiyu, 29. Taihuai, 30. Salawusu, 31. Dafa, 32. Dangcheng, 33. Baiquan, 34. Shandong, 35. Loufangzi, 36. Ejiawan, 37. Bantongcheng, 38. Rouyuan, 39. Shangkushui, 40. Shuangpuzi, 41. Xueguan, 42. Xigou, 43. Checun, 44. Longgugou, 45. Yaotougou, 46. Chenjiacun, 47. Laochihe, 48. Kansu, 49. Cangfanggou, 50. Penghu.*

horse is extinct in the wild: hunted for meat, and excluded from their pastures and watering points by domestic stock (Groves 1994). Only captive propagation in zoos has rescued the species from total extinction. At the end of World War II, there were thirty-one horses in captivity of which only nine reproduced. As a testimonial to the efforts of zoos to save this species, there are over a thousand Przewalski's horses at present (Boyd and Houpt 1994). The above-mentioned distributed area of the extant Przewalski's horse is just located in the arid region of central Eurasia, where Indian and East-Asian monsoons can not reach. The major factor to influence the climate of this region is Siberia-Mongolian cold high-pressure. Under the control of this high-pressure, the climate is very dry and cold, and the winter monsoon is very strong in this region. In the arid habitat of Przewalski's horses, annual rainfall is under 150–100 mm, even 50–30 mm or less in the extremely arid area; the annual rainfall has large variation, and there is no rain, sometimes during a whole year; the evaporation is very important, and the strong wind is frequent, with large daily differences in temperature. In this area mean temperatures in January are -15°C to -18°C, plunging to a minimum of -35°C (Bannikov 1958). Other animals in the distribution area of Przewalski's horses are mainly represented by large numbers of ungulates, such as *Equus hemionus*, *Saiga tatarica*, *Gazella subgutturosa*, *Procapra gutturosa*, *Camelus ferus*, and *Ovis ammon* all adapted to an arid climate. The main predator is *Canis lupus*, but small cats such as *Felis silvestris* and *Otocolobus manul* are also present. Desert hares (*Lepus* spp.) and rodents constitute the remaining terrestrial mammalian fauna (Groves 1994). In fact, the distributed region of the Przewalski's horse belongs to the western Desert Subprovince, Xinjiang-Mogolian Province, Central Asian Subrealm, Paleoartic Realm in zoogeography (Zhang 1999).

The distribution of the extant Przewalski's horse has not extended eastwards to northern China, although there is a transitional band between the western Desert and eastern Grassland Subprovinces of Xinjiang-Mongolian

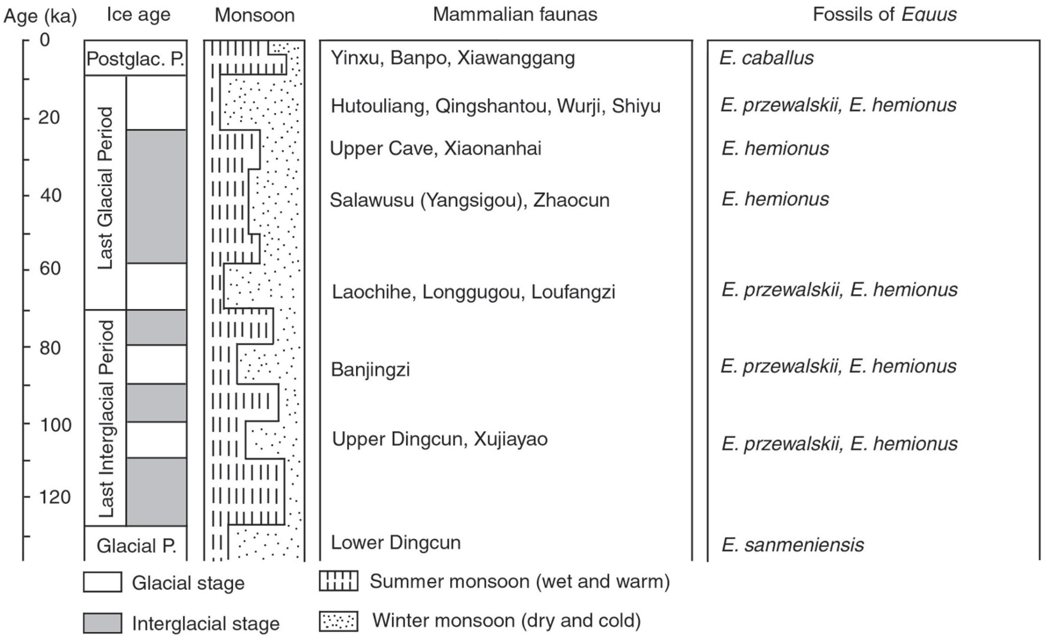


*Fig. 2. Climatic variations (after An* et al. *1991) and the* Equus *fossils of the mammalian faunas during the Late Pleistocene in China.*

Province. On the other hand, the distributed range of the Mongolian wild ass (*Equus hemionus*) in the same genus with the Przewalski's horse is relatively vaster than the latter, in Xinjiang, Ningxia, Qinghai and Inner Mongolia of China as well as in Central Asia widespread.

The above-mentioned facts indicate that the Przewalski's horse is a kind of desert animal that is strictly adaptable for arid and cold climate and environment, and live in the region of the strong winter monsoon.

### *Distribution of the Przewalski's horse during the warm period*

The distribution of the extant Przewalski's horse is strictly limited in ecological environment. Does it get evidence from the geological period? On other words, does the Przewalski's horse migrate along with the change of the prevailing region of the arid and cold winter monsoon? The earliest geological record of the Przewalski's horse in China comes from the upper part of the Dingcun Fauna at the beginning of the Late Pleistocene in China (You and Xu 1981). During the Quaternary in China, the East-Asian monsoon strongly influenced the climatic and environmental variations. An *et al*. (1991) established a variation model of the East-Asian monsoon according to the evidence of vegetation, desertification, eolian dust, paleosol, lake level change, and winter temperature of ocean surface layer (Fig. 2).

The stage from 10 ka to the recent, namely Holocene, is in the postglacial warm climate, and the summer monsoon is strong in northern China. Over hundred mammalian species have been discovered in northern China during this stage, but no clearly determined fossil of *E. przewalskii* is found in these faunas. The Yinxu Fauna was excavated from the famous site of the capital of Yin Dynasty in Anyang, Henan, with a $^{14}$C dating age of 3.4 ka (Institute of Archaeology 1991). This fauna includes *Equus caballus*, but feral animals mainly belong to the forest type, such as *Myctereutes*, *Ursus*, *Meles*, *Panthera*, *Epimys*, *Rhizomys*, *Tapirus*, *Hydropotes*, and *Pseudaxis* (Teilhard and Young 1936). *Rhizomys*, *Tapirus*, and *Hydropotes* are the animals lived in the Yangtze River valley and the south of this river, which implies that the climate during this stage was warm and humid. The Banpo Fauna is excavated from Xi'an, Shaanxi, with the $^{14}$C dating age of 6.7 ka (Institute of Archeology 1991). In this fauna, *Equus* sp. was considered to be domesticated perhaps (Li and Han 1959), and *Rhizomys* and *Hydropotes* also appear, which indicates that the climate in Xi'an during that time was warmer and wetter than present.

In the Holocene mammalian faunas of northern China, the appearance of *E. przewalskii* was reported only from the Dingjiapu Fauna in Yangyuan, Hebei (Jia and Wei 1980: Pl. I–3). The specimen from Dingjiapu is an isolated second premolar, however, it is very difficult to identify as *E. przewalskii* based only on a single find. This tooth may be a reworked outcome. The Dingjiapu fauna is collected from grail beds that is non graded, with gravel diameter of 20–40 mm, and the older second terrace contains the Hutouliang Fauna with fossils of *E. przewalskii*. In the fossiliferous beds of the Dingjiapu Fauna, there are a lot of coal fragments that is considered to be the reworked outcome of the Middle Jurassic Datong Coal Measures and collapsed blocks of the Early Pleistocene Nihewan Beds. It is very strange that both of *Coelodonta antiquitatis* and *Bos primigenius* belong to the Pleistocene, but they are present in the Dingjiapu Fauna of the Holocene at 3 ka, and that *Elephas maximus* adaptable for the tropical climate coexists with *Coelodonta antiquitatis* only in the Dingjiapu Fauna. In fact, these confusing problems are due to redeposition of fossils.

During the prevailing stage of the summer monsoon from 10 ka to the present, consequently, there is no appearance of the Przewalski's horse in the mammalian faunas of northern China. During the historical times, the county annals of Dunhuang, Gansu recorded that some people saw a flock of feral horses near the Crescent Spring of Dunhuang in 120 BC. If this record refers indeed to the Przewalski's horse, it proves that the Przewalski's horse distribution area was not limited only to northwestern China during the Holocene. Dunhuang is situated slightly more eastwards than Bajtag-Bogdo mountain of the eastmost distribution of the extant Przewalski's horse. By analyzing in detail the reason why the Przewalski's horse migrated eastwards during this stage, it appears that the climate might have a decisive effect on the geographical distribution of the Przewalski's horse. According to the pollen analysis, that stage was a little colder than the recent (Zhou *et al*. 1978), with little climatic fluctuations in the Holocene warm period. During the stage at around 120 BC, a little decrease of temperature indicated that the winter monsoon slightly strengthened while the summer monsoon slightly weakened. The Przewalski's horse migrated appreciably eastwards along with the slight strengthening of the winter monsoon, which implies that the Przewalski's horse is very sensitive to climatic variations.

### *Distribution of the Przewalski's horse during the cold period*

Contrary to the warm period, the Przewalski's horse appeared generally in the mammalian faunas of northern China during the prevailing stage of the cold and arid winter monsoon from 20 ka to 10 ka. The evidence can be found from several faunal assemblages.

The Hutouliang fauna was discovered in Yangyuan, Hebei, with $^{14}C$ dating age of 11 ka, and its 13 mammalian species are collected from the sandy loess, including *Microtus brandtioides*, *Citellus citellus*, *Myospalax fontanieri*, *Cricetulus varians*, *Canis lupus*, *Equus przewalskii*, *E. hemionus*, *Cervus* sp., *Bos* sp., *Gazella przewalskii*, *G. subgutturosa*, ?*Spiroceros* sp., and *Sus scrofa* (Gai and Wei 1977). *E. przewalskii* appears in the Hutouliang Fauna, and other mammals mainly are species adapted to desert or steppe habitats, such as *Microtus brandtioides*, *Citellus citellus*, *Myospalax fontanieri*, *Cricetulus varians*, *Canis lupus*, *E. hemionus*, *Gazella przewalskii*, and *G. subgutturosa*. On the other hand, forest species are scarcely represented in this fauna, which is identical with the background of the strong winter monsoon. Moreover, *Coelodonta antiquitatis* and *Palaeoloxodon namadicus* are discovered from the nearby sandy loess of the same horizon (Gai and Wei 1977), which further proves that the climate of this stage was very cold.

The Qingshantou fauna is located in Qianguo, Jilin, with $^{14}C$ dating age of 11 ka, and its 13 mammalian species are collected from the loess-like clayey, including *Marmota bobac*, *Citellus dauricus*, *Microtus btandti*, *Myospalax armandi*, *M. psilurus*, *Allactaga sibrica*, *Nyctereute procynoides*, *Vulpes* sp., *Equus przewalskii*, *Coelodonta antiquitatis*, *Sus scrofa*, *Bison* sp., and *Cervus* sp. (Jin *et al*. 1984). Besides *E. przewalskii*, more frigid desert mammals are present in the Qingshantou Fauna, such as *Citellus dauricus* and *Coelodonta antiquitatis*. Steppe rodents, such as *Marmota bobac* and *Allactaga sibrica*, are dominant, reaching 46%. This indicates that the climate during this period was colder and more arid in the most prevailing stage of the Dali Ice Age in China.

The Wurji fauna belongs to Balinzuo, Inner Mongolia, with $^{14}C$ dating age of 20 ka, and its 14 mammalian species are collected from the loess-like clay, including *Myospalax armandi*, *M. aspalax*, *M. psilurus*, *Allactaga sibirica*, *Spermophilus undulates*, *Canis lupus*, *Mustela sibirica*, *Crocuta ultima*, *Equus przewalskii*, *E. hemionus*, *Coelodonta antiquitatis*, *Bison* sp., *Gazella przewalskii*, and *Pseudaxis* sp. (Lu *et al*. 1986). Most of mammals from the Wurji fauna belong to desert or steppe forms, including *E. przewalskii*. Micromammals have the high proportion of 36 % in this fauna, such as *Myospalax*, *Allactaga*, and *Spermophilus*. Ungulates are very abundant, such as *Equus*, *Coelodonta*, *Bison*, *Gazella*, and *Pseudaxis*. The components of the Wurji fauna show the characteristics of the arid and cold prevailing region of the winter monsoon.

During the period between 20 and 10 ka, there are more mammalian faunas with *E. przewalskii* in northern China, including Xibaimaying in Yangyuan, Hebei with a series of U/Th dates ranging between 18–15 ka (Xie and Yu 1989), Xueguan in Puxian, Shanxi with $^{14}C$ dating age of 14 ka (Wang *et al*. 1983), Shanchengzi in Benxi, Liaoning with uranium series age U/Th 18 ka (Museums of Liaoning and Benxi 1986), and Angangxi in Qiqihar, Heilongjiang with $^{14}C$ dating age of 12 ka (Huang *et al*. 1984).

The eastmost mammalian fauna with *E. przewalskii* is the Penghu fauna, and it is collected from the seabed of the Penghu channel in Taiwan, dated to 15–10 ka (Gao

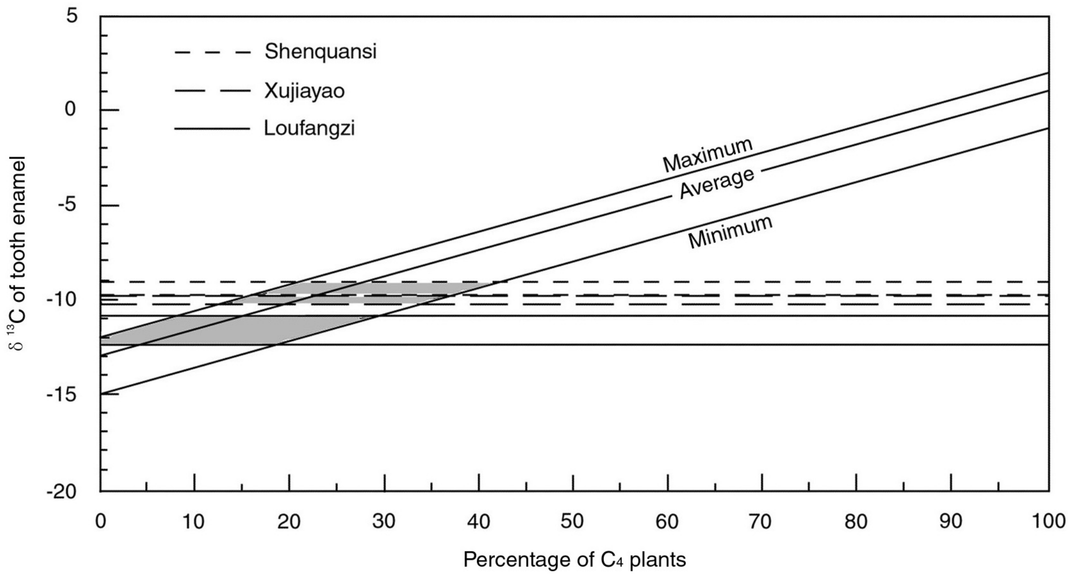


*Fig. 3. Isotopic variations of Carbon observed on tooth enamel analysis of* Equus przewalskii *from the Late Pleistocene in China.*

1982). *Elaphurus menziesianus* and *Bubalus youngi* are also included in the Penghu fauna, and their appearance in the water area of the South China Sea is relatively infrequent, because they are more usually distributed in the north. Gao (1982) considered that the Penghu fauna migrated from northern China because of the temperature decrease during the last fastigium of the Dali Ice Age. The appearance of *E. przewalskii* in the Penghu indicates that mammals in the north, especially in the arid and cold environment of northwestern China, can migrate to southeastern China along with the advancement of the winter monsoon. The direction from the distribution of the extant Przewalski's horse in northern Xinjiang to the Penghu district corresponds exactly to the advanced or retreated route of the East-Asian monsoon from northwest to southeast.

Consequently, the distribution of the Przewalski's horse is controlled by the spatio-temporal variation of the East-Asian monsoon (Deng 1999b). The Przewalski's horse is a typical semi-desert animal adapted to arid and cold climates. It seems that the strengthened or weakened variations of the East-Asian monsoon, stimulates the Przewalski's horse to migrate eastwards or westwards. The Przewalski's horse show to be very sensitive to climatic variation, could thus be regarded as an indicator for environmental changes.

### *Carbon stable isotope analysis of the horse enamel*

$C_3$ plants have $\delta^{13}C$ values ranging from about -23‰ to -34‰ with an average of -27‰ while $C_4$ plants from -9‰ to -17‰ with an average of -13‰ (Bender 1971; Winter *et al*. 1976). Soil carbonate and carbonate in tooth enamel of herbivorous mammals is significantly enriched in $^{13}C$ compared to source carbon. The enriched extent of the enamel carbonate is about 12–15‰. The tooth enamel from an animal with pure $C_3$ diet has a $\delta^{13}C$ value from -15‰ to -12‰ with an average of about -13‰ while that derived from pure $C_4$ diet has a value from -1‰ to +2‰ with an average of about +1‰ (Lee-thorp and van der Merwe 1987, Deng *et al*. 1999, 2002). Therefore, we can reconstruct distributions of $C_3$ and $C_4$ vegetations in geological history based on carbon isotopes of fossil soil and mammalian tooth enamel. $C_3$ plants include trees, most shrubs and many cool-season grasses, while $C_4$ plants include mostly warm-season grasses. $C_3$ grasses currently are restricted to cooler high latitude and altitude environments, and can also grow in the understory of forests. On the other hand, $C_4$ grasses distribute mainly in tropical and subtropical regions.

The isotopic values yielded from tooth enamel of the Przewalski's horse originate from northern China. The fossil localities include Shenquansi (age: 35 ka, $\delta^{13}C$: -9.31) in Yangyuan, Hebei; Loufangzi (age: 65 ka, $\delta^{13}C$: -11.73) in Huanxian, Shaanxi; Xujiayao (age: 105 ka, $\delta^{13}C$: -10.09) in Yanggao, Shanxi (Fig. 1). In the habitat of the Przewalski's horse during the Late Pleistocene, the $\delta^{13}C$ values ranged from -11.73‰ to -9.31‰ with an average -10.57‰, indicating that $C_4$ plants were rare (about 20%), and $C_3$ plants dominant (about 80%) (Fig. 3). In the typical region of summer monsoon in southern China, $C_4$ grass makes up 70% in the open district near 23° N (Ehleringer *et al*. 1987). In the steppe of northeastern China between 40° and 50° N, $C_4$ grass still makes up 40%, because the summer monsoon can influence this region (Yin and Wang 1997). In modern China, $C_4$ plants decrease progressively from southeast to northwest, and the climate becomes cold and dry from warm and wet along this direction. Therefore, temperature and humidity are significant conditions influencing the distribution of $C_3/C_4$ vegetation in China (Yin and Li 1997).

**Discussion about the age of some mammalian faunas**

There are many dating methods in the Quaternary geology, such as $^{14}C$, paleomagnetic, uranium series, fission track, ESR and others. However, these methods have more or less problems. Therefore, dating data must be analyzed comprehensively under combination with other evidences. As a result, the Przewalski's horse can be regarded as a climatic indicator to correlate to the climatic variation. According to this method, some ages of mammalian faunas are discussed hereby.

The Upper Cave fauna, excavated above Locality 1 of the Peking Man site in Zhoukoudian, Beijing, includes very abundant mammalian species (Pei 1940). Among the mammals *E. przewalskii* is absent. So we believe that this indicates a fauna belonging to the strong summer monsoon. The age of the Upper Cave fauna is generally considered to be 18 ka, however, it is a prevailing stage of the winter monsoon in northern China at 18 ka (An *et al*. 1991). On the other hand in the Upper Cave fauna, *Paguma larvata*, *Cynailurus* cf. *jubatus*, *Elephas* sp., and *Rhinoceros* sp. adapted to warm climate of the south were identified, which again emphasizes that this assemblage does not belong to a fauna of the winter monsoon. As a result, the age of 18 ka does not match the environment of this fauna. In fact, this contradiction is caused by the wrong viewpoint of the simultaneity between the Upper Cave culture and fauna. According to the excavation report of Pei (1940), mammalian fossils are collected from the cave basement, but cultural beds are situated above it. Therefore, the mammalian fossils are not simultaneous with the cultural beds. Chen *et al*. (1992) used AMS-$^{14}C$ to date the age of mammalian fossils from this fauna, and indicated that the cave basement deposit was around 34 ka and 27 ka. This time interval was in the prevailing stage of the summer monsoon, and it is identical with the environment of this fauna. Thus the age of the Upper Cave fauna at 18 ka should be revised.

The Laochihe fauna was excavated in Lantian, Shaanxi, and it includes 19 mammalian species, such as *Microtus brandtioides*, *Cricetulus varians*, *Canis lupus*, *Vulpes* sp., *Meles leucurus*, Mustelidae gen. et sp. indet., *Crocuta* cf. *ultima*, *Panthera tigris*, *Equus przewalskii*, *E. hemionus*, *Coelodonta antiquitatis*, *Moschus* sp., *Pseudaxis hortulorum*, *Megaloceros* cf. *ordosianus*, *Hydropotes* sp., *Capreolus manchuricus*, Bovidae gen. et sp. indet. (Ji 1974). The components of the Laochihe fauna is similar to those of the Salawusu fauna (Qi 1975; Deng 1999a). The pollen analysis for the strata bearing the Laochihe fauna shows the appearance of spruce and fir woodlands in this region, and the average temperature during that time was 8° C lower than the present (Ji 1974). In the Laochihe fauna, extinct species account for 42%, while 32% in the Salawusu fauna. According to the comprehensive correlation, the age of the Laochihe fauna should be in the glacial stage during 70–60 ka, and slightly earlier than the age of the Salawusu fauna. The Longgugou and Loufangzi fauna with *E. przewalskii*, respectively in Qingyang and Huanxian, Gansu (Ting *et al*. 1965; Xue 1982), should be simultaneous with the Laochihe fauna.

The Xujiayao fauna is excavated from the Paleolithic site in Yanggao, Shanxi, and its mammalian fossils include *Ochotona* sp., *Myospalax fontanieri*, *Microtus brandtioides*, *Coelodonta antiquitatis*, *Equus przewalskii*, *Gazella subguturosa*, and *Ovis* sp. (Jia and Wei 1976). Depended upon the mammalian components, the climate in this district during that time was continental, and the annual average temperature was lower than the present. *E. przewalskii* is a typical desert form; *Gazella subguturosa* is a desert or semi-desert species; *Coelodonta antiquitatis* is an indicator of the cold climate; *Microtus brandtioides* may be similar to the extant *M. brandti* in northeastern China and Inner Mongolia adapted to the arid steppe. Moreover, *Struthio* sp. is found in this fauna, and it also is a desert or arid steppe form. There are great disputes about the age of the Xujiayao fauna. Chen (1989) used uranium series and dated this to *circa* 125–100 ka. *E. przewalskii* is present in the Xujiayao fauna, congelative folds are developed in this stratigraphical section, and spruce pollen has a large proportion. These features imply a character of the ice age. In our opinion, the accurate age of the Xujiayao Fauna is 110–100 ka when the winter monsoon is very strong in the ice age.

The Shiyu site in Shuozhou, Shanxi provided many fossils of the genus *Equus*, including more than 4000 teeth. These teeth correspond to a minimum number of 120 individuals of *E. przewalskii* and 88 *E. hemionus* at least. The accompanying fossils include *Erinaceus* sp., *Crocuta* sp., *Panthera tigris*, ?*Myospalax* sp., *Cervus elaphus*, *Megaloceros ordosianus*, *Gazella przewalskii*, *G*. cf. *subgutturosa*, *Bubalus* cf. *wansijocki*, *Bos* sp., *Coelodonta antiquitatis* (Jia *et al*. 1972). The appearance of a lot of *E. przewalskii* should indicate the arid and cold climate. Moreover, *E. hemionus*, *Gazella przewalskii*, *G*. cf. *subgutturosa*, and *Coelodonta antiquitatis* also indicate the same climate. According to our viewpoint, the Shiyu fauna should be present in the prevailing stage of the winter monsoon. The $^{14}C$ dating age of the Shiyu Fauna is 28 ka (You 1982), however, this age is the interglacial stage of the strong summer monsoon when the climate is warm and humid contrary to the climatic characteristic of this fauna. In fact, the type of the stone artifacts in this site is more advanced compared with its age of 28 ka, such as flabellate stone nucleus, stone arrowheads, and perforate graphite adornments (Jia *et al*. 1972; An 1983). As a result, the age of the Shiyu fauna is questionable. On the basis of the variation model of the East-Asian monsoon, we judged that the age of the Shiyu fauna should be situated *circa* 20–16 ka when the winter monsoon is very strong in the cold glacial stage.

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