

Quaternary herbivore fauna in northeastern China: Evolution under climatic change

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Abstract Large herbivorous mammals from 10 representative Quaternary localities in northeastern China were studied. The evolution of these animals confirms Pei's law and Bergmann's rule. Of the three global cold periods in the Quaternary, the first and second are not well recorded in the region. The temperate period between these is well recorded. Records show that there was a sub-cold period (around 280 000 yr) during this temperate period. It remains to be confirmed whether this sub-cold period was limited only to Northeastern China. The third cold period is well recorded in the region. The fauna in this third period were composed mostly of temperate forms, as well as typical cold and pro-cold forms.

Key words: Northeastern China, Quaternary, Herbivore, Paleoclimate

1. Introduction

Plants are sensitive to climatic change, and their evolution has great influence on the herbivores that feed on them. Consequently, the morphological evolution, the faunal migration and exchange, and habitats of these herbivores reflect concomitant climatic changes [1-5]. Northeastern China is the northernmost region of China and is close to Siberia. This region is heavily influenced by Siberian cold fronts. This paper, based on the material from 10 important localities in Northeastern China, shows the effects of such climatic changes on three orders of herbivorous mammals, the Proboscidea, Perissodactyla and Artiodactyla (including omnivorous suids that also consume plants).

2. The Herbivorous Fauna

All together there are 22 genus and 32 species of large herbivorous mammals at the localities listed in Table 1. The actual number of species in all parts of the Northeast is undoubtedly greater. Among the listed species, the extinct ones total 14. The habitats or eco-patterns of the listed herbivores are mostly forests (e.g. moschids and cervids) or steppes (e.g. equids and bovinds). A few habitats are swamps (e.g. water deer, moose and buffalo), tundra (e.g. mammoths, woolly rhino, reindeer etc.), or mixed pattern (e.g. suids). In terms of body size, a few are small (e.g. musk deer, water deer and munjacks), or giant (e.g. mammoth and rhino), but the majority are medium- to large-sized. Based on stratigraphic records, the large and giant forms were evolved from smaller forms of Early Pleistocene or Pliocene age. Among the studied animals, *Sus scrofa*, *Sus lydekkeri*, *Capreolus manchuricus*, *Bison (Parabison) exiguus* were most abundant.

Early Pleistocene mammals are rare in Northeastern China. Middle Pleistocene mammals are found mostly in Liaoning Province, and Late Pleistocene mammals are found throughout the region. The distribution of Quaternary mammals appears to increase gradually and to expand progressively from the southern to the northern part of Northeastern China.

Mammuthus is the only genus of Quaternary Proboscidea in the region and was widespread. More than 60 localities yield mammoths in Helongjiang Province alone. About 28% of unearthed mammal fossils in Jilin Province are mammoths. In Liaoning Province, the localities yielding mammoths appear less numerous. The giant *Mammuthus (Parelephas) sungari*, evolved from less giant forms from Siberia, was extinct by the beginning of the Late Pleistocene. The smaller *Mammuthus primigenius* persisted through the Late Pleistocene until the beginning of the Holocene. Both forms went extinct after achieving climax, defined here by maximum size, high population density, and widest distribution.

Table 1 The large herbivorous mammals from 10 localities in Northeastern China. Abbreviation for localities: MH: Miaohoushan, JN: Jinniushan, GX: Guxiantun, YS: Yushu, XG: Xiaogushan, YJ: Yanjiagang, GL: Gulongshan, YL: Yunlianghe, QT: Qingtoushan, QG: Qianguo

Locality	MH	JN	GX	YS	XG	YJ	GL	YL	QT	QG
Absolute age(kya)	330	280	40	30	30	22	17	14	11	9
<i>Mammuthus primigenius</i>			+	15*	+	3	+	+		
<i>Mammuthus (Parelephas) sungari</i>		2		9		2				
<i>Equus hemionus</i>			+	14		1	14			
<i>Equus dalianensis</i>	6	+		17	+	4	21	+		
<i>Equus przewalskii</i>	+		+	8	+	1	16		+	
<i>Equus caballus</i>										+
<i>Coelodonta antiqutatis</i>		2	+	10	+	20	+	+	+	
<i>Dicerorhinus kirchbergensis</i>	12	2		4	+					
<i>Sus scrofa</i>			+	13	+	5	+		+	+
<i>Sus lydekkeri</i>	30	3								
<i>Moschus moschiferus</i>	+			1	+					
<i>Hydropotes inermis</i>	+	5								
<i>Muntiacus sp.</i>					+					
<i>Cervus (Rusa) unicolor</i>	+									
<i>Cervus (Sika) grayi</i>	+	3								
<i>Cervus (S.) nippon hortulorum</i>			+		+		+			
<i>Cervus elaphus xanthopygus</i>	1		+	9	+	1	+		+	
<i>Megaloceros ordosianus</i>		5	+	11	+	10	+			
<i>Megaloceros pachyosteus</i>	8									
<i>Alces alces</i>			+	6		3				
<i>Capreolus manchuricus</i>	1		+	16	+		+			
<i>Rangifer tarandus</i>			+							
<i>Buballus wansjocki</i>			+	5		1	+			
<i>Bison (Parabison) exiguus</i>			+	12		38		+	+	
<i>Bos primigenius</i>			+	7			+			
<i>Bos taurus</i>				6	+		+			
<i>Gazella przewalskii</i>	+	1	+	5	+	5	+	+		
<i>Pachygazella sp.</i>	1				+					
<i>Spirocerus kiakhtensis</i>	+	4					+			
<i>Naemorhedus goral</i>	+			+						
<i>Capra sp.</i>	5									
<i>Ovis ammon</i>			+							

* The number in the table indicates the minimum number of individuals of the corresponding species at that locality.

** The plus sign (+) indicates the presence of the species at the locality when the minimum number of individuals is too small or too difficult to estimate.

Among the Perissodactyla, equids were wide-ranging and abundant. The woolly rhinoceros, or *Coelodonta antiqutatis*, was wide-ranging and often appeared with mammoths, but never occurred further north than 60° N latitude. *Dicerorhinus kirchbergensis* are found in both Jilin and Liaoning Provinces, but in fewer numebers than *Coelodonta antiqutatis*.

The Artiodactyla were numerous in species and population. *Sus lydekkeri* was abundant but restricted in Liaoning Province and became extinct by the Late Pleistocene. *Sus scrofa*, a smaller form than *S. lydekkeri*, is found in all three provinces and survives to the present. The same is the case for musk deer. *Cervus (Sika) grayi*, *Megaloceros pachyosteus* and *M. ordosianus* went extinct in the Late Pleistocene, while the other cervids persisted to the present. Among the extant forms, reindeer do not occur south of Heilongjiang Province, and moose, no further south than Jilin Province. Among the bovids, *Buballus wansjocki*, *Bison (Parabison) exiguus* and *Spirocerus kiakhtensis* became extinct at the end of the Late Pleistocene.

When compared to geographically adjacent areas, *Mammuthus (Parelephas) sungari*, *Equus dalianensis*, *Alces alces*, *Rangifer tarandus* and *Bison (Parabison) exiguus* are absent from other parts of China, while forms from northern and northwestern China, such as *Palaeoloxodon*, *Equus sanmenensis*, *Paracamelus gigas*, *Megaloceros flabellatus*, *Buballus teilhardi* and *Spirocerus hsuchiayaoca*, are absent from the northeast.

3. Discussion

One of the general evolutionary tendencies of mammals in northeastern China is an increase in body size. This is in accordance with Pei's law^[6] which states that evolutionary lineage of mammals begins with a small form and increase in body size gradually to a large or even giant form, or until reaching the climax of its evolution, before the animal begins a decline and eventually becomes extinct. The increase in body size and mass is brought about by natural selection favoring large body size in cold climate and abundant food resources, because larger body sizes retain body warmth better than smaller ones as illustrated by Bergmann's rule. The abundance of food is controlled by natural factors such as the temperature, the abundance of sunshine, water and soil, etc. Plants on which the herbivores feed are sensitive to climatic change. When the climate becomes unfavorable to a certain plant, the plant will decline and consequently that will cause its consumers to decline in number. Under these circumstances, the smaller-size animals can survive better than the larger-size ones since the former need less food than the latter. Therefore, based on the evidence of the region's faunal evolution, there was a significant climatic change during the Pleistocene of northeastern China consisting of periods having climates favorable for cold tolerant forms alternating with periods having climate favoring temperate forms.

Not far from continental northeastern China, Pleistocene fossils such as *Palaeoloxodon namadicus*, *Mammuthus* sp., *Coelodonta antiquitatis*, *Cervus elaphus*, etc. were collected from the bottom of the Bohai Sea. South of the above localities, similar faunal assemblages were reported from Penghu, Taiwan Strait. The Penghu fauna includes *Equus przewalskii*, *Elaphurus menziesianus* and *Bubalus youngi*. Further south, Pleistocene mammals such as *Cervus eldi* were reported from the sea floor of the Beibu Gulf. The authors have examined some of the fossils found at the above mentioned sea floors. East of the Bohai Sea, Pleistocene fossil mammals were reported from the bottom of the Seto Inland Sea, West Japan^[7]. The Seto fauna are similar to that of Locality 1 of the Zhoukoudian Peking Man Site. Therefore, the sea floor fauna are found throughout East Asia. The fossils from the sea floors are well-preserved and show no trace of long-distance transport. They are evidently the remains of animals that lived on dry land there when sea level was far below its present level. During glacial periods sea levels were as much as 40 meters lower than today. On the other hand, in western Europe, there were three important cold periods when Siberian fauna migrated there. These faunas have been correlated with the oxygen isotope Stage 16 (620,000 – 655,000 yr), 6 (127,000 – 183,000 yr) and 2-4 (11,000 – 68,000 yr) respectively^[1]. The cold tolerant fauna migrated from Siberia to western Europe during these periods. Studies of Chinese loess by Kukla^[8], and Kukla and An^[9] show that the cold periods did exist in China during the Pleistocene and can be correlated with classical European glacial stages. Alternating cold and temperate climates during the Pleistocene were ultimately controlled by changes of the average incoming solar radiation in the winter half year of the northern hemisphere^[10], or by slow changes in the geometry of the earth's orbit. Therefore, it was a global phenomenon. It is this

phenomenon that influenced the dispersal events, or the variation in the geographic distribution of cold or temperate animals and their development.

There are few mammalian fossils in the strata deposited during the first Pleistocene cold period (620,000 – 655,000 yr) in northeastern China. The fauna between the first and second cold periods (183,000 – 620,000 yr), such as the Miaohoushan fauna (about 330,000 yr) consist solely of temperate forms. However, the Jinniushan fauna (about 280,000 yr), consist mostly of the temperate forms, had some cold forms (e.g. *Mammuthus sungari*, *Coelodonta antiguitatis*). This suggests that there was a sub-cold period around 280,000 yr in this region. The fauna from the second cold period and from between the second and third cold periods are few. In the third cold period (11,000 – 68,000 yr), the records are numerous, such as Guxiangtun, Yushu and Qingtoushan. In this period, the cold and pro-cold forms were numerous, prevalent, and persistent, while the temperate forms such as *Equus hemionus*, *E. dalianensis*, *E. przewalskii*, *Sus scrofa*, *Cervus nippon*, *C. elaphus*, *Megaloceros ordosianus*, *Capreolus manchuricus*, *Bison exiguus*, *Bos primigenius*, *Gazella przewalskii* etc. were also abundant and persistent. After the third cold period, northeastern China returned to a temperate period. The cold forms such as mammoths and woolly rhinoceros went extinct. Pro-cold forms such as reindeer and moose are now limited only in the northern parts of northeastern China.

4. Conclusion

Based on fossil mammal fauna, there was a sub-cold period within the temperate period between the first and second cold periods in northeastern China although it needs to be confirmed whether or not it was a local event or a larger scale one. The mammoth and woolly rhino reached Liaoning, the southern part of northeastern China, during this sub-period (around 280,000 yr).

The fauna of the third cold period of the region were composed of cold forms as well as temperate forms, the latter, the majority. It can be concluded that the temperature during the period did decrease, but not by much. Greater snow and glacial accumulations formed during the longer winters of this period in the higher latitude regions and in turn reflected more solar radiation than during temperate periods. This caused a great decrease in temperature and an increased mass of ice in the mountains and polar regions. It can also be inferred that the mammoths were pushed southward as the sea level dropped and the polar ice caps and mountain glaciers in the high latitude grew in volume during this cold period.

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